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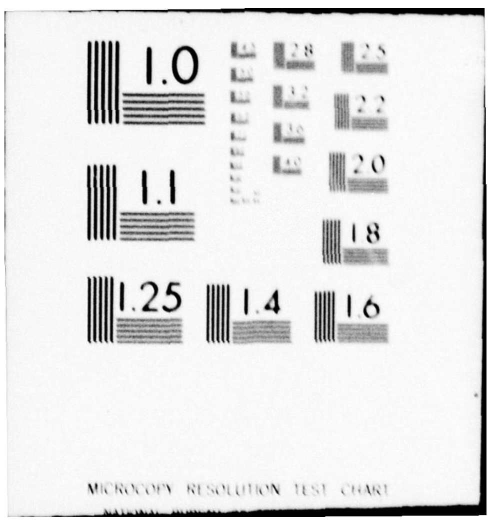
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MULTI-SERVICE TEST AND EVALUATION: MAVERICK TWO-SIDED TEST DESIGN (COMBAT HUNTER PHASE III)

Volume I. Main Paper and Appendix A.

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25 January 1972

MEMORANDUM FOR DIRECTOR OF DEFENSE RESEARCH AND ENGINEERING

SUBJECT: Multi-Service Test and Evaluation, MAVERICK Two-Sided Test Design (U)

I. FOREWORD

The abstract of WSEG Report 181 is contained in Section II below. Detailed WSEG comments are contained in Section III.

II. ABSTRACT

Title: WSEG Report 181, "Multi-Service Test and Evaluation, MAVERICK Two-Sided Test Design (U)," January 1972.

Conducted by: WSEG For: DDR&E

of this report is

Purpose: To develop a detailed test design for the two-sided test of the MAVERICK (AGM-65) weapons system against a simulated Soviet combined arms unit in a European environment. Data from the resulting test is to be utilized in an operational evaluation of the MAVERICK weapons system.

Methodology: Following a successful small-scale experiment (WSEG S-160), a detailed technical investigation of the missile seeker operation was conducted. In addition, an exploration of such factors as terrain, ground cover and weather was made to identify operational conditions which should be examined during a two-sided test. As a result of this work, four operational factors were selected for control during the test that do not constrain unnecessarily the free play of the exercise. A realistic threat was developed and concepts for tactical employment of the MAVERICK aircraft and the simulated Soviet combined arms unit were obtained from the Services. These factors were amalgamated to produce a test design which consists of 22 sets of conditions yielding 1584 data points. Other operational factors, which are not controlled, but which are expected to affect MAVERICK performance or aircraft attrition, will be observed and assessed.

III. WSEG COMMENTS

This report is the third increment of the MAVERICK Multi-Service Test and Evaluation series of reports developed in response to a Director of Defense Research and Engineering memorandum of 19 March 1971. This test design and summary plan for operational evaluation of the MAVERICK weapons system are fully responsive to the task directive.

The next incremental report will be the WSEG operational evaluation of the performance of the MAVERICK weapons system against elements of a Soviet combined arms unit in Europe.

The report notes that, in conjunction with the data derived from the two-sided test, and other data developed by WSEG, additional inputs from other agencies will be required to complete the planned evaluation. MAVERICK post-launch reliability and lethality estimates, and probabilities of maintaining lock-on under various operational conditions, including countermeasures, are essential. These additional data should be made available for evaluation by 15 June 1972.

Two items in the test design and evaluation plan should be noted:

1. One measure of effectiveness in the evaluation plan is the expected number of tank kills per MAVERICK weapons load expended. The test will record any armored vehicle killed, i.e., armored personnel carrier or air defense vehicle, as a tank. The terms tanks and armored vehicles are used interchangeably throughout the study.

2. The expected aircraft attrition measured is only that attributable to short range air defense weapons accompanying Soviet assault forces and does not include the effects of longer range SAM's such as the SA-4/6 systems or enemy interceptors.

The study cites the need for an auxiliary study effort to determine the threshold performance that would justify MAVERICK procurement. WSEG concurs that such an analysis, or one which addresses the comparative effectiveness of MAVERICK with other competitive weapons systems, is desirable in considering the next MAVERICK production decision.

Arthur W. Oberbeck

ARTHUR W. OBERBECK
Lieutenant General, USA
Director

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STUDY S-393

MULTI-SERVICE TEST AND EVALUATION: MAVERICK TWO-SIDED TEST DESIGN (COMBAT HUNTER PHASE III)

Volume I: Main Paper and Appendix A

S. L. Waller, *Project Leader*

January 1972

This report has been prepared by the Systems Evaluation Division of the Institute for Defense Analyses in response to the Weapons Systems Evaluation Group Task Order DAHC15 67 C 0012-T-169, dated 20 July 1971.

In the work under this Task Order, the Institute has been assisted by military personnel assigned by WSEG.

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PREFACE

This study presents a test design for two-sided testing of the MAVERICK weapon system against a simulated Soviet combined arms unit. It also presents a summary plan for operational evaluation of the MAVERICK system based on the two-sided test data. This study was conducted under WSEG Contract DAHC 15-67-C-0012-T-169.

Volume I contains the Main Paper and Appendix A; Volume II contains classified Appendices B and C (SECRET NOFORN).

The principal participants of this joint IDA and WSEG project team included:

Larry F. Brown, LTC USAF	Earl A. Thomas
Richard P. McLean, LTC USA	William C. Tyrrell, Col. USA
Joseph A. Navarro	Sylvia L. Waller
Frederick Stahl	Francis R. Walsh, Capt. USN

Dr. Navarro is the OT&E Study Director; Mrs. Waller served as Project Leader and authored the Main Paper; and Capt. Walsh served as the WSEG military point of contact. The author(s) of each appendix are cited therein. Other contributors to the study included G. Brown, D. Dobson, E. Marcuse, C. Tiffin, S. Ugel, and Col. H. Moreland, USAF.

Reviews by Dr. George James, Raytheon, and Dr. Lawrence Starkey and Dr. William Schultis, IDA, who served as the Technical Review Committee, are gratefully acknowledged.

Chapter I

INTRODUCTION AND SUMMARY

This study presents a detailed test design for the MAVERICK two-sided test (COMBAT HUNTER Phase III), to be conducted during May and June 1972 at Fort Riley, Kansas. It also presents a summary plan for evaluation of the operational performance of the MAVERICK weapon system against a Soviet combined arms unit.

This chapter describes the background of the two-sided test program and a summary of test design concepts. Chapter II presents the operational evaluation plan; Chapter III, the plan for analysis of the two-sided test data; Chapter IV, the statistical design for the two-sided test; Chapter V, the test scenarios; and Chapter VI, a description of test resources, instrumentation, and test data requirements.

A. BACKGROUND

By SECDEF memorandum of 11 February 1971, WSEG was requested "to participate on a trial basis in the design, conduct and evaluation of a joint operational test of the MAVERICK weapon system and an Army combined arms unit." The Institute for Defense Analyses was tasked by WSEG to conduct the study and provide technical analyses.

1. Preliminary Study

The preliminary effort of this program resulted in WSEG Staff Study 160, comprising IDA Paper P-765.[1] This phase of

[1] WSEG Staff Study 160, Multi-Service Test and Evaluation, MAVERICK, April 1971, SECRET.

the effort addressed the question: What should be the principal evaluation and test objectives of an OT&E MAVERICK program that could best be pursued in a two-sided test? It also suggested concepts for a MAVERICK two-sided test and evaluation program, and established initial facility and resource requirements.

Based on this preliminary analysis, it was recommended that:

- Testing (and evaluation) be completed in time to support the next MAVERICK production decision.
- Two-sided testing be limited to MAVERICK performance up to simulated launch using captive missiles.
- Post-launch MAVERICK performance and aircraft attrition due to air defense fire be represented by data from simulations and controlled testing.
- Testing be conducted in two phases:

  Phase I--To be of limited scope to evaluate testing concepts and explore potential problem areas in MAVERICK two-sided testing.

  Phase II--To be of broader scope to be conducted at several geographic locations to represent both climatic and geographic conditions characteristic of Europe.
- An easily transportable instrumentation system be procured to provide time-position-event data on all air and ground test units.
- Test resources consist of 6 to 10 operational F-4D/E and A-7D MAVERICK-equipped aircraft to be provided by the Air Force; and a simulated company-size Soviet combined arms unit to be provided by the Army as a target array.

2. Phase I Test Design Experiment[1]

The recommended first phase field experiment was conducted at Hunter Liggett Military Reservation (HLMR) in September 1971,

[1]Designated by the Air Force as COMBAT HUNTER Phase I. COMBAT HUNTER, the Air Force TAC MAVERICK OT&E Program, has four phases: Phase I - the two-sided test design experiment; Phase II - development of tactics; Phase III - the two-sided test; and Phase IV - live testing of first production missiles.

taking advantage of a combined arms unit ground array being used for other Army testing. This test design experiment confirmed the feasibility of the two-sided testing, analysis, and instrumentation concepts proposed in the preliminary study. In particular, it confirmed the overall applicability of the range measuring system (RMS) as the primary instrumentation system for the two-sided test.[1]

B. TWO-SIDED TEST

A design for the two-sided test program (recommended as Phase II in the preliminary study) is summarized below.

1. Location and Period of Testing

The two-sided test program will be conducted during May and June 1972 at a single test site, Fort Riley, Kansas, rather than at several geographical sites as originally suggested. This decision by DepDDR&E(T&E) was based on the following factors:

- The small variations in European-type terrain and climate available at appropriate test sites during spring testing, compared with the larger costs of multi-site testing.
- The variations in terrain at Fort Riley that are representative of several different aspects of European terrain.
- A time period limited to approximately 6 weeks, starting in May during which all testing must be completed. The required pretest checkout period of the integrated air/ground complex of instrumentation and players cannot start until early May 1972 upon completion of COMBAT HUNTER Phase II since the same MAVERICK-equipped aircraft and crews will be used for both programs. The two-sided testing must be completed by the end of June to provide for operational

[1]Several modifications are required in the RMS software currently being used in the HLMR system in order for the system to be effectively used with high performance aircraft. These requirements are detailed in Appendix A.

evaluation of results (and associated reviews by appropriate organizations) in time to influence the October 1972 MAVERICK production decision.

2. Test Resources

The test design is based on continuous availability during the test period of:

- A minimum of two MAVERICK-equipped F-4 aircraft and two MAVERICK-equipped A-7 aircraft.[1]
- Four crews for each type aircraft.
- A simulated company-size Soviet combined arms unit to represent the enemy target array.
- Sufficient elements to represent a U.S. defensive ground force (two tanks and four APCs are planned).

Since only two each of MAVERICK-equipped F-4 and A-7 aircraft are being made available by TAC for this test, a total of four aircraft for each trial, rather than the original preference for four of each type, is specified. This limitation may impose a minor artificiality in the test by the necessary utilization of two different types of aircraft in a flight where flights of four tactical aircraft are needed to represent operational tactics. This test is designed to represent attacks against ground targets by the MAVERICK system only. All aircraft involved in attack passes should be MAVERICK-equipped.

3. Scenarios

The test scenarios are described in detail in Chapter V; two ground scenarios are used:

- An attack scenario, where MAVERICK is required for close air support of U.S. defensive ground units against an attacking combined arms unit.

---

[1]At least three MAVERICK-equipped aircraft of each type are required for availability of two aircraft during each test trial.

- An exploitation scenario, where MAVERICK is required for use against an enemy combined arms unit exploiting a breakthrough.

4. Tactics

Air and ground units will use operational tactics for the tactical situation posed in each test trial. There are no unnatural constraints deliberately placed on tactics by the test design. It is assumed in the test that MAVERICK has previously been employed in combat against targets in a combined arms unit sufficiently often that the tactics to be used have become doctrine.

Part of the pretest period of checkout of the integrated air/ground complex of instrumentation and players should be used to evaluate the air and ground tactics planned. In this way, there is an opportunity to introduce minor improvements in tactics prior to the collection of test data. (This represents what normally occurs in combat situations after initial contact with enemy forces.) Once the test has started, however, it is suggested that whatever basic tactics are selected as appropriate for the situation represented by any given trial be employed by all aircraft engaged in that trial. All data collected during the test period will be used for evaluation independent of the tactics used.

Since only a company-level front-line element of a Soviet combined arms army is represented, the air tactics must take into account the threat from air defense weapons of combined arms units on either side of the one being attacked. The threat from SAM units employed to the rear of the combined arms company must also be considered during the attack scenario.[1]

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[1]Appendix C, Chapter V, describes the air scenario and SA-6 threat, and discusses the impact of this threat on the test. Aircraft tracks recorded during the test will be analyzed to assess potential exposure to air defenses outside the target array under the tactical conditions postulated.

The SAM threat is addressed in the test design in the following way:

- During specified test conditions of unlimited and medium altitude weather ceilings, it is presumed that effectiveness envelopes have been reduced by ECM and suppression tactics sufficiently to provide clear air space for unrestricted MAVERICK delivery tactics from the FEBA up to and above the attacking combat units.
- During specified low ceiling conditions, it is presumed either that SAMs may not be suppressed and there is a requirement for low altitude flight profiles to approach the target array below SAM effectiveness envelopes or that the ceiling restriction represents a weather ceiling.

5. Statistical Test Design

The statistical test design may be summarized by the following features:

- It is a factorial test design using four controlled variables: flight ceilings (three variations); shadow conditions (two variations); terrain clutter backgrounds (two variations); and type scenarios (two variations). Only combinations of the four controlled conditions considered operationally feasible are included.
- The design is described by 22 combinations of these conditions. Each combination represents a separate tactical situation or trial.
- Trials are scheduled in a random sequence for each of the two shadow conditions.
- Three separate simulated operational sorties ("attacks")[1] are to be conducted during each test sortie by each of four aircraft. This will provide a minimum of three independent sets of performance data for each of four aircraft under each trial situation.
- Four crews per aircraft type should fly an equal number of designated trials.

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[1]"Attack," as used in this study, is a simulated operational sortie during which as many passes are made against the target array as are required to launch a MAVERICK weapons load.

The test will yield data on 132 simulated operational sorties ("attacks") for each type aircraft during the 22 trials. This will result in a total sample size for the two types of aircraft of 1,584 data points on simulated MAVERICK launches, based on 72 simulated launches per trial (six per aircraft per attack).[1]

6. Instrumentation

The following primary types of instrumentation are required: range measuring system (RMS) to record time-position-event data on test vehicles, voice recording system (VRS), ADU boresight cameras, MAVERICK video recording systems, and aircraft boresite (still) cameras. These systems and the test data to be recorded by each are described in detail in Appendix A.

C. OPERATIONAL EVALUATION PLAN

As input to the planned evaluation of MAVERICK's combat potential against armored vehicles in a Soviet combined arms unit, several types of data are required in addition to the data to be derived directly from the two-sided test. These requirements and the organizations suggested to be tasked to provide the data prior to completion of the two-sided test are as follows:

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[1] If only four MAVERICKs are carried by F-4 aircraft, these numbers would be reduced accordingly.

Evaluation Input Requirements	Suggested Agency To Provide Data
Post-launch performance data:	
Reliability estimates (launch and in-flight)	MAVERICK SPO
Lethality against Soviet armored vehicles	DoD Joint Technical Coordinating Group for Munitions Effectiveness
Probability of maintaining lock-on, given lock-on and launch under operational conditions (to include effects of active countermeasures)	MAVERICK SPO (supported by USACDC to prescribe operational target conditions)
Air defense unit kill probabilities, given engagement under operational conditions	WSEG/IDA[1]
European weather and terrain conditions	WSEG/IDA[1] (supported by ETAC)

For the two-sided test and evaluation results to provide meaningful inputs to the next SECDEF MAVERICK production decision, an auxiliary study effort is required to establish threshold values of performance that would justify procurement. This effort should be started as soon as possible to ensure that the type of MAVERICK performance data to be provided by the two-sided test and evaluation can be of greatest value to the Defense Systems Acquisition Review Council (DSARC) in its deliberations on the October 1972 MAVERICK production decision.[2]

D. PROPOSED TEST AND EVALUATION SCHEDULE

The following test schedule is proposed to meet the requirements of the test design and for timely evaluation of MAVERICK performance:

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[1]To be accomplished within the MAVERICK Project.

[2]DSARC is tentatively scheduled to meet in September 1972 to consider recommendations for the October decision.

Prior to 1 May -	All instrumentation systems in place and checked out.
8 May -	All players available with individual instrumentation checked out.
8-12 May -	1. Checkout of the total integrated complex of instrumentation and player units including assessment of equipment operability, data collection procedures, and player procedures. 2. Analysis of data from sample trial situations for minor adjustment of preestablished tactics and procedures.
15 May -	Start of two-sided test.
15 May-15 June -	Completion of 22 trials (approx. 15 test-flying days).
Within 1 week after completion of each trial -	Complete trial package of reduced data delivered to WSEG.
One week after completion of test program -	Delivery to WSEG of all basic test data collected, including video tapes, RMS tapes, reduced VRS recordings, ADU boresight camera film, aircraft still camera photographs, weather data, pilot briefing and debriefing logs, and ground observer logs.
By 22 June -	All data required for operational evaluation provided to WSEG.
15 September -	Completion of operational evaluation of MAVERICK capability against combined arms units.

Chapter II

MAVERICK OPERATIONAL EVALUATION PLAN

This chapter describes the plan for evaluation of the performance of the MAVERICK weapon system against tanks in a Soviet combined arms unit in Europe. The planned evaluation is based on input data from the two-sided test results, post-launch test data, simulations, and analyses.

A. EVALUATION OBJECTIVES

The principal evaluation objective of the two-sided MAVERICK test program in support of the forthcoming production decision was stated in WSEG Staff Study 160:

> To assess the tactical value of having F-4D/E and A-7D MAVERICK air-to-ground weapon systems in the TAC inventory for use against armored vehicles employed in Soviet combined arms units.

To assess tactical value of the MAVERICK weapon system requires a comparison of performance and cost (both program costs and attrition replacement costs) with alternative antitank air-to-ground weapons. This approach was proposed in WSEG 160. DDR&E(T&E), however, indicated that such a cost-effectiveness comparison will be accomplished by another agency of OSD and suggested that this two-sided operational evaluation confine its scope to MAVERICK alone. In line with this suggestion, the following more limited operational evaluation objective has been formulated relative to MAVERICK's potential combat capability against armored targets:

To determine the extent to which MAVERICK can be expected to destroy armored vehicles in attacks on Soviet combined arms units in the European theater; and at what cost in attrition of U.S. aircraft to air defense units during attacks.

To meet this objective, two quantitative overall measures of effectiveness--expected number of tanks[1] killed and expected number of aircraft attrited--are planned to be used, related to those sets of operational conditions[2] expected to be encountered most often in European combat. The use of these measures of effectiveness separately and in combination will illuminate those operational conditions in which the MAVERICK weapon system can be used most effectively, and those in which its usefulness could be severely constrained. They will also be useful to illustrate the tradeoffs between aircraft attrition and tank kills per combat sortie (i.e., weapons load expended) under different operational conditions.

As described in WSEG 160, the ultimate purpose of this operational test and evaluation program is to provide the decisionmaker with a higher confidence in the operational performance of the MAVERICK weapon system than presently exists, in order to support the MAVERICK production decision. An evaluation of MAVERICK alone, however, cannot provide answers to the following essential questions: Is it worth having MAVERICK in the inventory for use under only those operational conditions in which the expected number of tank kills per aircraft attrited in an attack is relatively high? And what threshold values constitute a sufficiently high exchange ratio between tanks killed and aircraft killed to justify continued procurement of MAVERICK under any conditions?

[1]The terms tanks and armored vehicles are used interchangeably in this study.

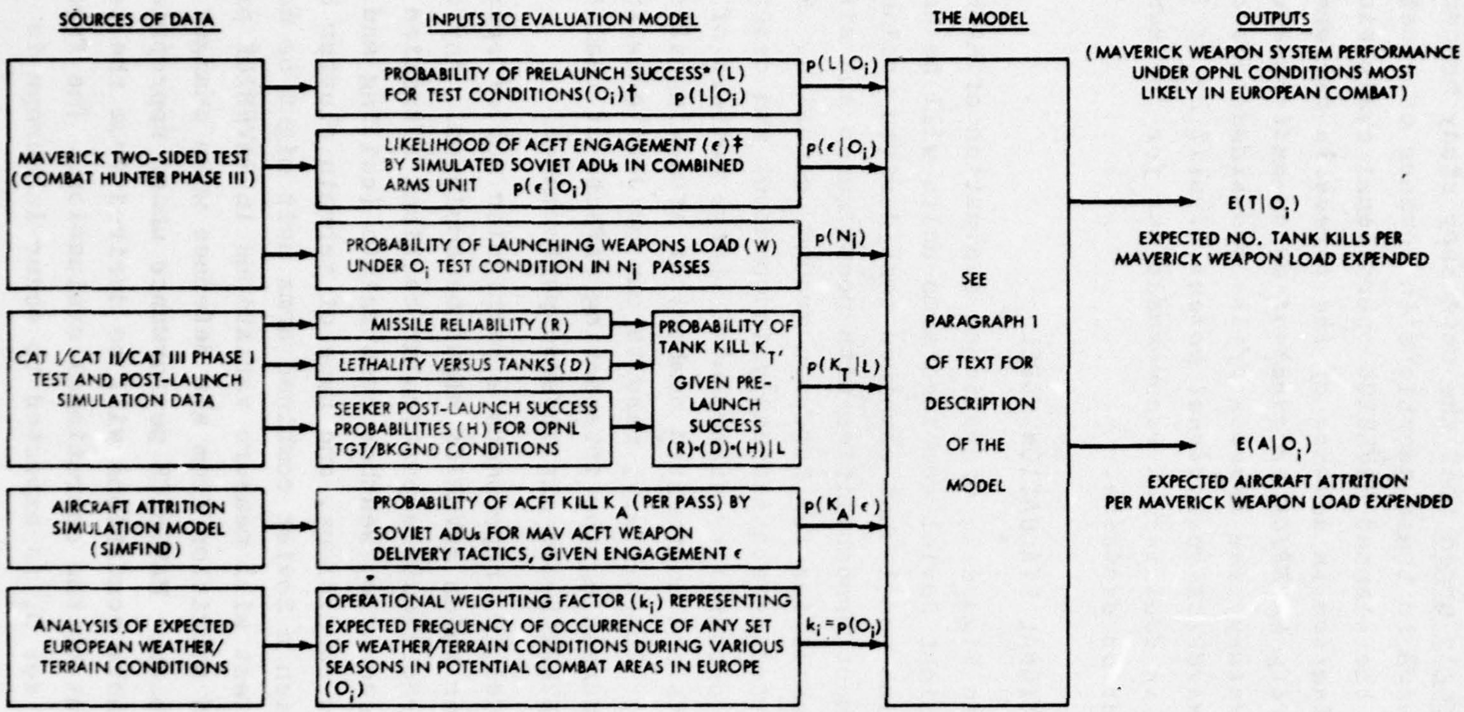
[2]Operational conditions include conditions of environment, terrain, Soviet equipment, doctrine and tactics, and the scenarios in which MAVERICK might be employed against Soviet combined arms units.

It is strongly urged that the necessary study be conducted to provide answers to these questions in advance of receiving the results of the planned MAVERICK operational evaluation. *Without determination in advance of the threshold performance that would justify MAVERICK procurement as an anti-tank weapon in the TAC inventory, the results of the two-sided test and the evaluation of MAVERICK operational potential will be of limited value to DSARC in deciding on recommendations for the next MAVERICK production decision.*

B. THE OPERATIONAL EVALUATION MODEL

As shown in Figure 1, operational evaluation of MAVERICK performance against Soviet combined arms units will be based on an expected value model that combines test-derived prelaunch and ADU engagement probabilities with post-launch and aircraft attrition probabilities for European ground scenarios. Model inputs are treated as statistically independent and described by conditional probability statements. Large numbers of combined arms units and unattrited numbers of attacking aircraft are postulated. In this way, results can be derived without specifically addressing the interacting effects of real time attrition on MAVERICK and air defense performance.

In the model, O_i represents a particular set of operational conditions under which MAVERICK might be employed. Any one set of conditions represents a particular tactical situation involving the scenario, weather constraints (ceiling and visibility), shadow conditions, and type of terrain clutter background over which a Soviet combined arms unit might be moving. The two-sided test will measure variations in MAVERICK prelaunch performance and attrition from air defenses with changes in each of these variables. MAVERICK performance under appropriate combinations of these conditions will be derived from the test results as input to the operational evaluation. The frequency with which any set O_i is expected to occur in Europe is



*Prelaunch Success (L): Valid lock-on and simulated launch (i.e. launch signal) prior to minimum range against a true (i.e., threat vehicle) target.

†O_i is the i^{th} set of conditions.

‡ Acft Engagement (ϵ): Track and fire upon an aircraft within maximum gun envelope.

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Figure 1. MODEL FOR EVALUATION OF MAVERICK WEAPON SYSTEM PERFORMANCE AGAINST SOVIET COMBINED ARMS UNITS IN EUROPEAN COMBAT

represented by an operational weighting factor k_i, described in Section C.

The subsections that follow describe: the expected value model and its output measures of effectiveness; the inputs to the evaluation required from testing, simulations, and analyses; and the plan for combining the data from all these sources to obtain the desired operational performance measures.

1. The Model for Developing Principal Measures of Effectiveness

The principal outputs from the MAVERICK evaluation will be two quantitative probabilistic measures of performance, presented as a function of those operational conditions expected most often in European combat:

(1) Expected number of tank kills per MAVERICK weapons load delivered in an operational sortie.

(2) Expected aircraft attrition per weapons load delivered.

a. Expected Number of Tank Kills per Weapons Load Delivered

The expected number of tank kills per weapons load delivered E(T), the principal measure of effectiveness of MAVERICK as an air-to-ground weapon system, is based on two principal performance factors. The first is the expected number of prelaunch successes[1] per weapons load delivered. This is the product of the number of missiles carried W times the probability of prelaunch success p(L) under any given operational condition O_i. The second performance factor is the probability of tank kill $p(K_T)$ given prelaunch success L under the specific launch target and background conditions that apply. This latter factor includes missile reliability (including launch reliability), lethality, and the probability of the missile seeker retaining

[1]Prelaunch success is defined as valid lock-on and simulated launch (i.e., launch signal) against a real target prior to the minimum range limitation of the missile.

target lock-on during missile flight under the various dynamic post-launch target/background conditions that are expected to occur in combat. The expected number of tank kills per operational sortie for condition set O_i may thus be written

$$E(T|O_i) = Wp(L|O_i)p(K_T|L,O_i) .$$

The expected tanks killed per operational sortie E(T) for a European scenario at any particular season of the year can be expressed as

$$E(T) = \sum_{i=1}^{n} E(T|O_i)p(O_i) ,$$

where $p(O_i)$ (referenced in Figure 1 as the k_i weighting factor) is the probability that the i^{th} operational condition will occur ($i = 1...n$) during a particular season of the year. The set $p(O_i)$ describes the expected conditions for a European scenario for the season considered.[1]

Expected tanks killed E(T) involves the total MAVERICK weapon system both prior to and after launch. It includes not only the missile performance but also the effects of weapon delivery tactics, airframe performance, and pilot performance. Pilot performance is reflected in his ability to detect visually armored vehicles in time to launch successfully and his ability to discriminate between real and false targets, such as bushes and rocks.

b. Expected Aircraft Attrition per Weapons Load Delivered

Expected aircraft attrition per MAVERICK weapons load delivered E(A) is a critical measure of how effectively the enemy counters the MAVERICK system. This measure is the number

[1]See Appendix C for a description of European scenarios.

of aircraft lost in delivering a number of MAVERICKs equal to a weapons load. The attrition measured is only that attributable to short range air defense weapons accompanying Soviet assault forces and does not account for the effects of longer range SAMs as, for example, SA-6 systems.

The value of the measure E(A) will vary depending on:

- The number of passes needed for an aircraft to deliver its load of weapons
- The conditions and occurrences of engagement of the aircraft by ADUs
- The probability that the aircraft is destroyed in each engagement with an ADU that does occur.

In general terms the expected attrition is arrived at by first selecting the probability of kill for each engagement of each pass, from which the probability of survival of the aircraft for each pass can be calculated. Next the expected attrition for each attack is developed from the probabilities of survival for each pass. The average expected attrition for all attacks under a single combination of operational conditions (that is, test conditions) is calculated from the attrition values for each attack. Finally the expected attrition for a European environment can be computed using these average attrition values and the k_i weighting factors mentioned above.

The equations for these calculations for each aircraft attack during a trial are as follow. First, the probability of engagement by the m^{th} air defense unit $p(\epsilon_m)$ during the k^{th} pass P_k under test conditions O_i as determined from the test can be stated as

$$p(\epsilon_m|P_k,O_i) \text{ .}$$

This probability is either zero or one and is conditional on the survivability of the aircraft up to the beginning of the pass. From the application of the SIMFIND model, a corresponding probability of kill $p(K_A)$ for each aircraft type under the

specific conditions of engagement is selected. Thus the probability an aircraft survives the m^{th} air defense unit during the k^{th} pass is

$$p(S_m|P_k,O_i) = 1 - p(K_A|\epsilon_m)p(\epsilon_m|P_k,O_i) ,$$

and the probability an aircraft survives the pass $p(S|P_k,O_i)$ is the product of the probabilities of surviving each air defense unit.

The expected number of aircraft lost in completing all passes of each attack (that is, the delivery of a weapons load) is[1]

$$E(A|O_i) = \sum_{k=1}^{N_i} [1 - p(S|P_k,O_i)] ,$$

where N_i is the number of passes flown in the attack under conditions O_i.

The <u>average</u> attrition experienced per type aircraft to expend a weapons load under conditions O_i can now be found by averaging the expected attrition per attack over all attacks conducted under the O_i test trial condition; that is

$$E(A|O_i) = \frac{1}{6} \sum_{j=1}^{6} E(A_j|O_i) ,$$

where two F-4s and two A-7s each conduct three attacks during each trial.

The expected attrition incurred while delivering a weapons load of MAVERICKs in the European scenario for a particular season of the year is found by weighting the attrition value

[1]This measure has been selected since it can be directly related to "expected number of tanks killed per weapons load delivered," the MAVERICK effectiveness measure described in paragraph a. Several other probabilistic measures of aircraft attrition of interest could also be derived at this point, including (1) probability of aircraft kill per attack, (2) probability of attrition on the j^{th} pass, or (3) expected aircraft attrition per type air defense system.

obtained above for various conditions by the relative weighting factor for each condition $k_i = p(O_i)$. The formula for expected attrition per type aircraft is thus

$$E(A) = \sum_i E(A|O_i)p(O_i) \ ,$$

where $\sum_i p(O_i) = 1$, and i ranges over the sets of conditions for which tests were conducted.

This development of expected attrition rests on several assumptions. Notably, it is assumed that within each pass MAVERICKs are launched before attrition occurs, and that there is probabilistic independence between attacks.

2. Inputs to the Model

In order to obtain the measures of performance described above, the operational evaluation plan will combine data inputs derived from the two-sided testing with data from simulations and post-launch testing, and with an analysis of expected operational conditions. The type of data inputs required from each of these sources are summarized below.

a. Two-Sided Test Inputs

(1) Prelaunch Success Probability - *The probability that MAVERICK can be successfully launched against armored vehicles under a simulated European combat environment.*

Successful launch requires the following conditions:

- Detection by the pilot of an array of armored vehicles deploying in a realistic scenario.
- Selection by the pilot of a specific target to be attacked.
- Lock-on by the seeker.
- Launch against a real target prior to minimum launch range.

(2) Likelihood of Engagement - *The probability that aircraft will be engaged by air defenses of the simulated combined arms unit during the attack*, and the parameters of such engagements needed to compute attrition levels

Engagement of an aircraft is defined here as aircraft tracked and fired upon by the ADU or SA-7 while the aircraft is within gun range.

The plan for deriving the above evaluation inputs from the two-sided test data is presented in Chapter III. This test data analysis plan is similar in concept to the plan presented in the Phase I Experiment Supplement[1] to WSEG 160, with modifications based on the experiment experience. The statistical design of the two-sided test to provide statistically significant data for analysis is described in Chapter IV.

b. Inputs From Simulations and Post-Launch Testing

Two separate inputs are required to reflect "end-game" performance of MAVERICK and ADUs: probability of tank kill by MAVERICK given a valid launch signal; and probability of aircraft kill by ADUs given engagement of an aircraft.

(1) Probability of Tank Kill - *The probability that the MAVERICK missile, given a valid launch signal, will be successfully launched and will destroy the target.*

This requires data on three aspects of post-launch performance:

- Missile reliability (including launch).
- Missile lethality against armored vehicles.
- The probability that the missile will maintain target lock-on during its trajectory for the dynamic target/background/visibility conditions that apply.

Appendix B presents the total requirements and a suggested approach for providing the post-launch inputs required for the evaluation. Post-launch seeker performance needs to be explored for those operational conditions under which there exist large uncertainties regarding the seeker's ability to maintain lock-on after launch. That is, a program consisting of captive flight testing and laboratory simulations is required to support the two-sided test and evaluation. This program should derive a

[1]Addendum to WSEG Staff Study 160, July 1971, including IDA Paper P-782.

set of MAVERICK post-launch success probabilities[1] for a variety of climatic and geographic conditions, target/background contrast ratios, and ground tactics that might be used in combat. Specifically, data on missile post-launch probability of maintaining lock-on is needed under the following types of operational conditions[2] for the basic reasons indicated (a more complete matrix of post-launch data requirements is contained in Table B-2 of Appendix B):

- Tank (with normal combat camouflage) stationary and moving on grass to verify performance against European type terrain and as a control set to measure variations caused by other conditions.
- Performance near foliage to measure effects of partial concealment and potential transfers of lock-on to the foliage and/or its shadow during missile flight.
- Performance under partial obscuring and shadow producing effects of battlefield dust (or smoke).
- Performance against a mottled background such as produced by declivities on the ground and/or grass color and bare spot variations. A mottled background provides a source of contrasts that may cause transfer of lock during missile flight.
- Performance during firing of tank guns. This provides a natural optical transient that may produce a breaklock effect on the battlefield.[3]
- Performance under overcast conditions. Overcasts produce an absence of shadows and lower the ambient light level. Although the primary effect may be to inhibit target acquisitions and lock-on, the effect of the presence or absence of shadows on seeker post-launch performance is unknown.

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[1]Post-launch success is defined as the missile maintaining target lock-on after launch, given launch under any particular condition relative to the target (range, elevation, azimuth, sun angle, and aircraft speed), and given a reliable missile.

[2]Preliminary investigation indicates that post-launch testing and/or simulations under these conditions have not been conducted.

[3]Active tank countermeasures, if tactically feasible, should also be considered. The Deputy Test Director/Army has initiated a program to investigate appropriate active countermeasures that might be employed in combat.

- Performance against backgrounds of different colors and textures. The effects of color (green, tan, brown, etc.) and background texture (grass, sand, rocks, etc.) on the MAVERICK seeker are not known with precision.

(2) Probability of Aircraft Kill - *The probability that the aircraft will be killed, given engagement by an ADU.*

This is the second type of evaluation input required from simulation sources. For this purpose, data are required on aircraft vulnerable areas, and on the technical and operational characteristics of the Soviet air defenses.[1] These, along with relative locations of guns and aircraft during an attack, are used as inputs to an air attrition model that provides estimates of aircraft kill probability for the attack conditions of interest. The WSEG/IDA SIMFIND air attrition models[2] will be used. How the attrition data are to be combined with air defense engagement data from the two-sided test is described briefly in Chapter III.

c. Inputs From Analysis of Expected Operational Conditions

An analysis of expected European seasonal weather/terrain conditions compared with the conditions under which the two-sided test data will be obtained should yield the following data from which operational weighting factors, or the probability that a particular set of conditions will occur in European combat, can be derived:

(1) The frequency of weather conditions (i.e., ceiling/visibility, shadow conditions, ambient illumination, etc.) expected in Europe at different potential combat areas and seasons of the year, so that the results can

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[1]Annex 1 of Appendix C provides Soviet weapon characteristics to be used in the evaluation.

[2]SIMFIND Models of Anti-Aircraft Gun Systems, IDA Research Paper P-564, March 1970.

be weighted to represent performance under the most likely combinations of conditions when combat might occur.

(2) The terrain background variations expected in European combat areas, in order to relate the background at Fort Riley to Europe insofar as the terrain affects performance.

Four separate operational factors, which are expected to significantly affect the performance of MAVERICK against armored vehicles, will be controlled in the planned two-sided test. These conditions (i.e., controlled variables of the test design) are summarized in Table 1. Chapter IV describes how these conditions define the statistical design of the two-sided test and the rationale for their selection.

Table 1. CONTROLLED OPERATIONAL FACTORS

Controlled Test Variable	Controlled Operational Factor	Variations			
Maximum run-in altitude	Operational ceilings	3	Unlimited	~5,000 ft[a]	Low[b]
Background clutter conditions in vicinity of armored vehicles	Areas of ground operations	2	Primarily open area	Large amounts of foliage	
Scenario conditions	Scenarios	2	Attack scenario	Exploitation scenario	
Target shadow conditions	Mission times of day or type of day	2	Midday or overcast	Early morning or late afternoon (sunny days)	

[a]To correspond to a mid-ceiling weather condition on which international statistics are collected and that occurs frequently in Europe.

[b]As low as possible for the employment of MAVERICK as determined by the Air Force. This condition is expected to represent the low altitude approach tactics that would be employed where large concentrations of SAMs exist behind the approaching combined arms units, as well as a low ceiling weather condition.

Other operational factors that are expected to affect performance or aircraft attrition, but which will not be controlled in the two-sided test, include:

- Visibility (as it affects contrast ratio).
- Overcast (as it affects ambient illumination).
- Aircraft tactics during an attack (i.e., number of aircraft simultaneously attack, dive angle, multiple versus single launch, and lock-on and launch procedures).
- Aircraft tactics after an attack (i.e., pullout maneuver).
- Ground vehicle defensive tactics during an attack (i.e., attempted concealment, evasion, or other passive countermeasures).

During the test, these conditions, though uncontrolled, will be observed and will constitute the uncontrolled variables of the test. Their effects on MAVERICK performance and aircraft attrition will be assessed. Data derived from the MAVERICK Cat I, Cat II, and Cat III Phase I test programs will also be used, where appropriate, to extend the data base on conditions, such as visibility, where very limited data are expected to be obtained from the two-sided test under conditions known to have a significant effect on performance.

The ground environment to be provided by the Army should simulate to the maximum extent conditions representative of actual combat situations. This may involve the generation of gun smoke effects over the battlefield or the burst effects of artillery shells. Deliberate defensive tactics will include only those considered operationally feasible in a situation where prior knowledge is not available on the specific type of anti-tank weapons to be employed.

Chapter III

PLAN FOR ANALYSIS OF DATA FROM MAVERICK TWO-SIDED TEST

The general plan for analysis of the two-sided test data required as input to the operational evaluation is presented in this chapter. It includes the measures of performance, and the required types of data to be obtained from testing to provide these measures. The instrumentation by which the data are expected to be collected is described in Appendix A. For each measure of performance, statistical analyses of variance or regression analyses will be used to determine the operational factors that significantly affect performance.

A. PERFORMANCE MEASURES

1. Overall Measures of Peformance

The performance measures to be derived from the two-sided prelaunch test data include:

(1) The probability distributions associated with MAVERICK being successfully launched against tanks in a combined arms unit.

(2) The probability distributions associated with the MAVERICK launch aircraft being engaged[1] by air defense units (ADUs) in a combined arms unit.

Both measures consist of several conditional probabilities. These probabilities will then be combined to provide the

[1]That is, acquired, tracked, and fired upon while the aircraft is within gun range.

performance measures derivable from the two-sided testing for input to the MAVERICK operational evaluation described in Chapter II. As discussed in Chapter II, the MAVERICK prelaunch success and ADU engagement probabilities so derived represent MAVERICK performance only under the specific conditions of the test. The extent to which these test conditions represent expected operational conditions and the percentage of time selected sets of conditions can be expected to occur in combat will be important aspects of the operational evaluation.

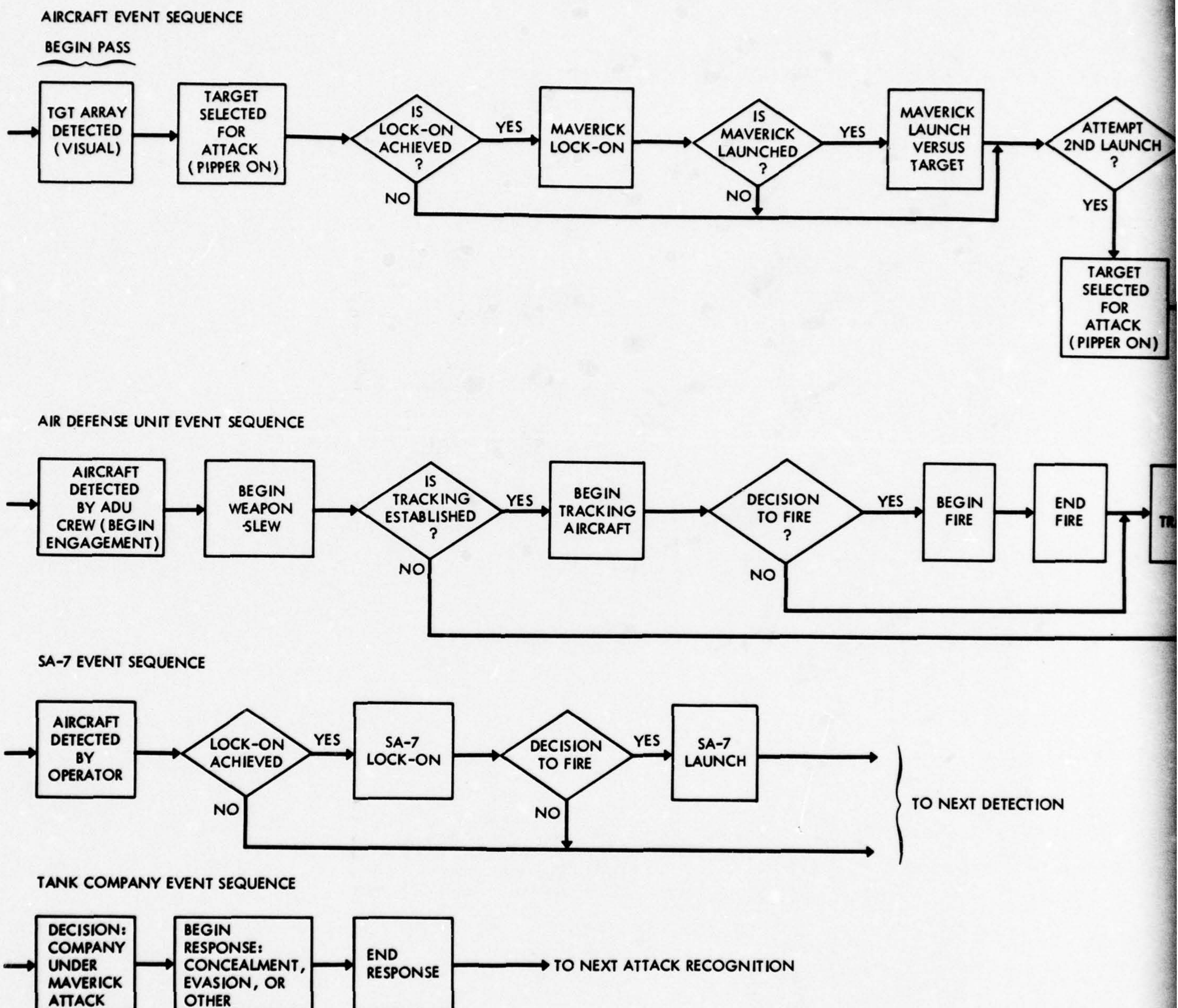
Figure 2 indicates the interacting events that can occur in aircraft, tanks, and air defenses during aircraft attack passes. Time position tracks on all players (air and ground) and the times when events occur are required in order to obtain through data processing (both computerized and manual) slant ranges between units, background conditions, and vehicle performance at the time of each critical event. (Appendix A describes the requirements for reduced data.) The probabilities of events occurring under different combinations of variables will yield a matrix of expected performance under the test conditions.[1]

2. MAVERICK Launch Probabilities

From data obtained for each aircraft test sortie[2] during each trial (i.e., for each combination of test conditions), the following conditional probability and cumulative distributions relative to MAVERICK will be derived from test results:

[1]Although this evaluation is limited to MAVERICK weapon system performance, it should be noted that the data derived in the two-sided test can be of value to DoD beyond its immediate use in evaluating MAVERICK. For example, both the data on pilot detection of armored target arrays and the data on aircraft exposure to air defenses under various attack situations could be used directly as inputs to operational evaluations of other air-to-ground weapon systems.

[2]See Table 4, Chapter IV, for the definitions of trial, test sortie, attack, pass, and simulated launch that are used herein for the two-sided test design.


AIRCRAFT EVENT SEQUENCE
BEGIN PASS
TGT ARRAY DETECTED (VISUAL)
TARGET SELECTED FOR ATTACK (PIPPER ON)
IS LOCK-ON ACHIEVED ?
YES
NO
MAVERICK LOCK-ON
IS MAVERICK LAUNCHED ?
YES
NO
MAVERICK LAUNCH VERSUS TARGET
ATTEMPT 2ND LAUNCH ?
YES
TARGET SELECTED FOR ATTACK (PIPPER ON)
AIR DEFENSE UNIT EVENT SEQUENCE
AIRCRAFT DETECTED BY ADU CREW (BEGIN ENGAGEMENT)
BEGIN WEAPON SLEW
IS TRACKING ESTABLISHED ?
YES
NO
BEGIN TRACKING AIRCRAFT
DECISION TO FIRE ?
YES
NO
BEGIN FIRE
END FIRE
SA-7 EVENT SEQUENCE
AIRCRAFT DETECTED BY OPERATOR
LOCK-ON ACHIEVED
YES
NO
SA-7 LOCK-ON
DECISION TO FIRE
YES
NO
SA-7 LAUNCH
TO NEXT DETECTION
TANK COMPANY EVENT SEQUENCE
DECISION: COMPANY UNDER MAVERICK ATTACK
BEGIN RESPONSE: CONCEALMENT, EVASION, OR OTHER
END RESPONSE
TO NEXT ATTACK RECOGNITION

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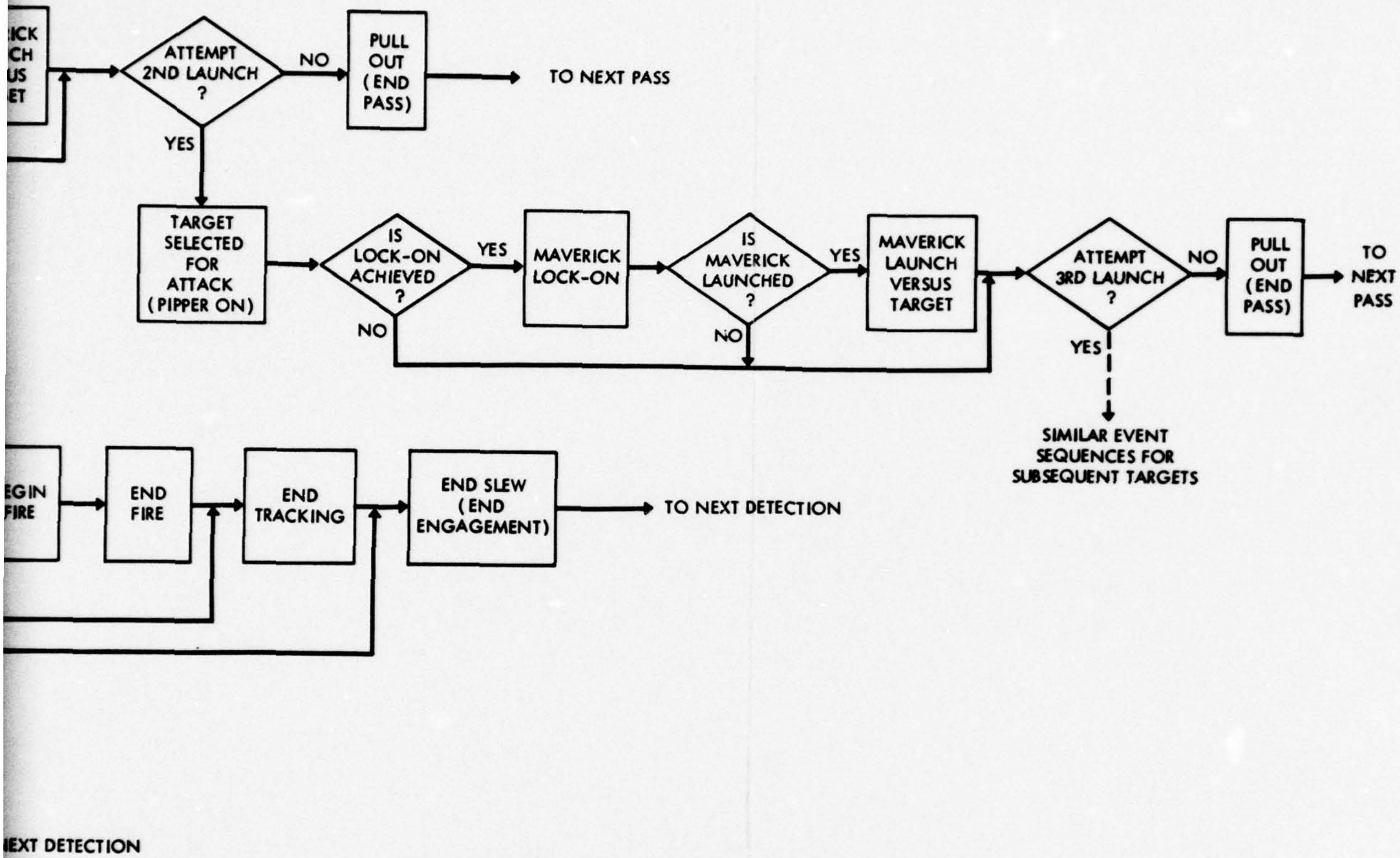

Notes: 1. Each box represents a possible event during a pass, conditional upon all previous events in a single path completed. Each diamond represents a branch point in the sequence of events.
2. Vehicle operations required for ADU and SA-7 employment not shown. Early warning events also not shown.

Figure 2. SEQUENCE OF EVENTS

2

For each attack:

- Range distribution and probability of an aircraft pilot visually detecting the array of target vehicles.

For each pass:

- Given detection of a target array, range distribution and probability of selecting the first target for attack (represented by "pipper on," with time of event approximated by "SLEW ENABLE").
- Given first target selection, range distribution and probability of MAVERICK locking on and launching[1] against the first and subsequent targets in the pass.
- Distribution of times between lock-on and launch, and between subsequent launches.
- Distribution of number of launches per pass.

For each launch:

- Having locked-on and launched, probability of launch completed within the MAVERICK launch envelope (prior to minimum range).
- Having launched a MAVERICK within launch envelope, probability that the launch was against a real target (i.e., threat vehicle), and distribution of slant ranges of all launches, launches against false targets, and launches against real targets.

The conditional probabilities relative to prelaunch success during each trial will be combined as shown below to obtain probabilities of prelaunch success per launch during an attack:

Probability of Valid Launch, Given a Launch $\left(\frac{\text{No. Launches With Lock-On}}{\text{Weapons Load Launched}}\right)$	X	Probability of Launch Within Envelope, Given a Valid Launch $\left(\frac{\text{No. Within Envelope}}{\text{No. Valid Launches}}\right)$	X	Probability of Launch at True Target, Given Valid Launch Within Envelope $\left(\frac{\text{No. Against True Targets}}{\text{No. Within Envelope}}\right)$	=	PROBABILITY OF PRELAUNCH SUCCESS GIVEN A LAUNCH

[1]"Launch" during the test is a simulated launch represented by a launch signal generated by the pilot. Target lock-on during launch constitutes a "valid launch."

The slant range distributions at which events occur, and the distributions of time between events, will be used in the analysis to identify the conditions and events that drive the ultimate quantitative prelaunch success ratios to be used as input to the operational evaluation.

3. Probabilities of Air Defenses Engaging Attacking Aircraft

For the controlled conditions of the test, the following conditional probability distributions relative to air defenses are considered necessary for the analysis:

- Slant range distribution of final launch per aircraft pass, point of closest approach to each ADU, and probability of aircraft within gun range of each ADU during an attack pass.
- Probability of at least one air defense unit detecting an attacking aircraft during a pass.
- Having detected an aircraft, probability of at least one air defense unit establishing a track of an attacking aircraft.
- Probabilities of one, two, or more air defense units tracking and firing upon a single attacking aircraft during a pass within maximum gun range.
- Distributions of duration of time aircraft are within ADU maximum gun range during a pass.
- Distribution of aircraft track characteristics (e.g., speed, dive angle, pullout g's, etc.) from final launch through pullout.
- Distribution of number of passes per attack for each trial.

The conditional probabilities relating to successful ADU engagement under each trial situation will be combined as shown below to obtain probabilities of successful engagement by each ADU per pass during an attack for each set of test conditions:

$$\begin{array}{c}\text{Probability of Acft}\\ \text{Within Gun Range}\\ \text{During a Pass}\\ \left(\dfrac{\text{No. Acft Passes Within Gun Range}}{\text{Total No. Passes During an Attack}}\right)\end{array} \times \begin{array}{c}\text{Probability of Acft}\\ \text{Being Tracked and}\\ \text{Fired Upon by ADU}\\ \left(\dfrac{\text{No. Acft Tracked and Fired Upon Within Gun Range}}{\text{Total No. Passes Within Gun Range}}\right)\end{array} = \begin{array}{c}\text{PROBABILITY}\\ \text{OF AIRCRAFT}\\ \text{ENGAGEMENT,}\\ \text{GIVEN A PASS}\end{array}$$

The distributions of track characteristics, ranges at which final launches within a pass occur, and times within gun range will be used in the analysis to identify the aspects of aircraft tactics related to test conditions that have the controlling influence on successful ADU engagement.

B. DERIVATION OF EVENT SUCCESS PROBABILITIES FROM TEST DATA

Each of the probability distributions described above will be obtained from the test data as follows:

(1) During each aircraft pass, the occurrence of a successful event is recorded and related to the relative range between attacker and target.[1]

(2) The ratio of the total number of successful events occurring to the total number of times in which the event could occur provides an event success ratio (as a cumulative function of range).

(3) For each set of controlled test variables, probability distributions of expected value of success as a function of range (and other non-controlled conditions affecting success) will be developed.

(4) The probability distributions representing the primary measures of performance from the test will then be derived by statistical techniques for combining the conditional probabilities. These measures of performance include probabilities of prelaunch success per launch, the probabilities of an aircraft being engaged by air defense units during a pass, and the number of passes per aircraft attack to expend a weapons load.

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[1] In the case of armored vehicle targets, range will be calculated to the centroid of the target array if target vehicles are within close proximity of each other.

(5) The auxiliary performance data recorded during each pass (such as times between events, etc.) will be tabulated and distributions derived.

(6) Analyses of variance will be used for each separate performance measure to determine which controlled condition has a significant effect on performance and the magnitude of this effect.

(7) Regression analyses will be performed on all the data to determine the effects on performance of the uncontrolled (but measured) variables. Some of these effects may be confounded with the controlled variables or their interactions. If the effects are large, however, the variables responsible for the effects can be determined.

Table 2 presents an estimate of the total amount of reduced data provided by the test design for analysis for each MAVERICK- and ADU-related event.[1]

Table 2. EXTENT OF TEST DATA ON MAVERICK- AND ADU-RELATED EVENTS

Type of Event	No. of Samples		
	Per Test (22 trials)	Per Trial (4 sorties)	Per Test Sortie
MAVERICK Prelaunch Activities[a]			
Target Array Detection (initial)	264	12	3
Launch Events (for weapons loads of 6 missiles per aircraft):			
Target Selection	1,584	72	18
Lock-on	1,584	72	18
Launch (valid? true target?)	1,584	72	18
ADU Events[a] (one quad 23mm; one twin 57mm; one SA-7):			
Aircraft detection	528-1,584	24-72	6-18[b]
Track	528-1,584	24-72	6-18[b]
Fire	528-1,584	24-72	6-18[b]

[a]Slant range and relative elevation between the target (tank or aircraft) and the weapon carrier (aircraft or air defense unit) at the time of each event are determined for each event.

[b]Assuming one ADU engagement per pass.

[1]A suggested data reduction plan is included in Appendix A. It is estimated that approximately 15 to 20 analysts during the test period (6 weeks) will be required at Fort Riley to produce a package of reduced trial data within 1 week after completion of each trial.

C. END GAME ANALYSES BASED ON TWO-SIDED TEST INPUTS

1. Expected Number of Tanks Killed per Attack Under Test Conditions

The probability of destroying a tank-type target under the conditions of the test, given prelaunch success, will be determined as follows:

(1) From the data obtained from Cat I, Cat II, and Cat III Phase I tests and post-launch simulations, families of curves of probability of maintaining seeker lock-on during missile trajectory will be plotted as a function of launch range for the spectrum of terrain/clutter/background, visibility, target motion, and deliberate CM conditions that may be expected in a combat environment.

(2) For each successful simulated launch accomplished during the two-sided test, the probability of maintaining postlaunch seeker lock-on will be selected from the curves for the appropriate target background condition and launch range.[1] The distributions of these probabilities will be plotted for all launches within each trial set of conditions and the average per trial computed.

(3) Each of these probabilities will be combined with appropriate estimates of missile reliability and of missile lethality against tanks (given a hit) to represent probability of tank kill, given prelaunch success, for each specific set of test conditions.

(4) These probabilities will be combined with the probabilities of prelaunch success (for the same set of test conditions) to represent probability of tank kill per launch under test conditions. The probability of tank kill per launch multiplied by the weapons load per aircraft will provide a measure of expected number of tanks killed per attack under test conditions.

2. Expected Aircraft Attrition per Attack Under Test Conditions

Probability distributions for aircraft attrition per attack during each trial will be derived by using the test data in

[1]Requirements for post-launch performance data are described in Appendix B.

combination with attrition curves developed from the SIMFIND air attrition model.

For each test pass in which the aircraft was within maximum gun range of an ADU and was engaged by the ADU, the probability of aircraft kill for that pass will be selected from a family of curves (developed from the SIMFIND model) for the appropriate track conditions of that pass relative to the gun position, the period of track, and the duration of fire. These conditional probabilities will be combined with engagement probabilities for each ADU for each pass in an attack to determine probability of aircraft survival on pass number 1, 2, 3, etc. These survival probabilities, as described in Chapter II, will be combined over all passes to arrive at an expected aircraft attrition rate per attack.

Chapter IV

TWO-SIDED TEST DESIGN

This chapter describes the recommended design for the two-sided test of the MAVERICK weapon system against a combined arms unit. It includes the test objectives, the statistical test design, a discussion of the controlled test variables, and a description of the composition of a test trial.

A. TEST OBJECTIVES

The objectives of the two-sided test are:

- To provide estimates of the probability of MAVERICK success in locking on and launching (simulated) against armored vehicles in representative combat situations.
- To provide estimates of the probability of MAVERICK aircraft being engaged by air defense units of a combined arms unit during combat sorties.

As described in Chapter II, the two-sided test is one of the principal sources of data for the MAVERICK operational evaluation. The unique aspect of the two-sided test is the bringing together of the principal adversaries in a realistic interacting environment in order to document their respective effects and effectiveness. Because their weapons are designed to be lethal, and because time and fiscal constraints preclude investigation of the absolute environment (terrain and weather), it is necessary to rely on other tests and analyses for lethality and weather probabilities.

B. TEST DESIGN

1. Purpose

The general purpose of the test design is to specify the range of conditions under which measurements of prelaunch capability should be obtained in order for test results to be most useful in representing combat performance in Central Europe.

The test is not designed to represent real time attrition effects between air and ground forces. Instead, the design is based upon separate analyses of each event occurring during MAVERICK attacks, as described in Chapter III. These events will be treated as statistically independent and described by conditional probability statements. This permits postulating for test purposes situations of unlimited numbers of ground targets and unattrited aircraft during each attack. Thus small numbers of ground and air forces can be used in the test to produce results for analysis representative of larger scale tactical operations.

2. Statistical Design of Test

The design of this two-sided test is characterized by 22 combinations of operationally representative conditions selected for measurement of MAVERICK performance. Under each set of controlled conditions (designated a "trial"), four aircraft (two F-4s and two A-7s) will be flown. Eight crews (four for each aircraft type) should be assigned, if possible, to fly designated trials during the test to determine the effects of crew variability on performance.[1] Eighty-eight test sorties will be flown.

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[1]The design can also accommodate the condition of a single set of crews to fly all trials as discussed in Subsection 2d.

a. Test Conditions

Factorial designs have been chosen to provide estimates of performance variations resulting from each of four selected test conditions: flight ceiling, terrain background, shadow condition, and ground scenario. These conditions have been selected as the controlled variables in the two-sided test on the following bases:

- They represent operational conditions that are expected to result in significant differences in performance.
- They do not provide unnatural constraints on the operational tactics (i.e., "free play") of the air and ground forces during the test.
- They are feasible to control during the test.

In addition to these controllable conditions, there are a number of potentially significant variables that are not feasible to control in an operational-type test; these include target/background contrast ratio at time of launch, sun angle, ambient light level, actual visibility, and tactics. These variables will be measured rather than controlled in the test, and to the extent feasible the effects of such variables upon the observed results estimated.

The number of variations selected for each controlled test condition is as follows:

- 3 Simulated Ceilings
  - C_1--unlimited ceiling
  - C_2--mid-ceiling condition
  - C_3--low ceiling restriction
- 2 Terrain Backgrounds
  - B_1--low clutter
  - B_2--moderate clutter

- 2 Shadow Conditions
  - S_1--no shadows
  - S_2--long shadows
- 2 Ground Scenarios
  - G_1--an attack scenario
  - G_2--an exploitation scenario

A discussion of the above conditions and the rationale for their selection are presented in Section 3.

b. <u>Factorial Designs</u>

The test design is shown in Table 3. It is described by two overlapping matrices of test conditions comprising two separate factorials. One test matrix, a 2^4 factorial design, compares all combinations of background, scenario, and shadow conditions (S_i, B_j, G_r) for two of the three ceilings (C_1 and C_2). This design comprises 16 trials and will determine direct and interaction effects on MAVERICK performance of background, shadows, and scenario for unlimited and mid-altitude ceilings.

The second overlapping matrix is a 3x3x2 factorial design that compares three combinations of shadow scenario conditions (S_1G_1, S_1G_2, and S_2G_1) with the three ceilings (C_1, C_2, and C_3) and the two clutter backgrounds (B_1 and B_2). This design comprises 18 sets of conditions and will determine the direct effects on performance of ceiling, as well as interaction effects of ceiling, background and shadow/scenario combinations for each ceiling condition.

Each combination of the four variables $S_iB_jC_kG_r$ to be tested represents a potentially different tactical situation that is considered operationally feasible. Within each trial, a minimum of three independent sets of observations on each event will be obtained from each of the four aircraft, and data on 72 total simulated launches recorded.[1]

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[1]This is based on a weapons load for each aircraft of six missiles. If only four missiles are (continued on next page)

Table 3. TEST DESIGN (COMBINATIONS AND SEQUENCE OF TRIALS)

Ground Scenario	Simulated Ceiling Restriction and Terrain Clutter Background					
	C_1B_1	C_1B_2	C_2B_1	C_2B_2	C_3B_1	C_3B_2
For Short (or No) Shadow Condition (S_1)						
G_1	(6)[a]	(11)	(3)	(10)	(7)	(9)
G_2	(1)	(8)	(4)	(2)	(12)	(5)
For Long Shadow Condition (S_2)						
G_1	(6)	(1)	(9)	(5)	(2)	(8)
G_2	(4)	(7)	(3)	(10)	X	X

[a]Numbers in parentheses indicate the preferred order in which trials should be conducted for each shadow condition. S_1 tests can be performed on either overcast days or during a short shadow period on sunny days. S_2 tests can only be performed on sunny days.

It should be noted in Table 3 that the combination of low ceiling condition C_3 with long shadows S_2 in an exploitation scenario G_2 is omitted. It is unlikely that long shadow conditions will occur in conjunction with a low weather ceiling;[1] however, the low ceiling C_3, long shadow S_2, and attack scenario G_1 combination of conditions has been deliberately retained to account for the attack situation where the presence of unsuppressed surface-to-air missile systems several kilometers

(cont'd) carried by F-4 aircraft, and six carried by A-7 aircraft, there will be data on a total of 60 simulated launches per trial.

[1]The long shadow, mid-ceiling combination has been retained in the matrix to represent conditions where scattered clouds may force MAVERICK operations below a medium ceiling cloud base.

behind an attacking ground company may impose an operational limitation on the altitude at which aircraft can safely approach the target area.

c. Sequence of Trials

Suggested sequences of running the 12 no-shadow trials and 10 long shadow trials are also presented in Table 3. Each is a random sequence designed to prevent inadvertent bias of the test results by unforeseeable factors that might be correlated with the order in which the trials are performed. It is not feasible to randomize with respect to shadow condition. On an overcast day, only S_1 trials can be run; on sunny days, either S_1 or S_2 trials can be run by selection of the time of day for the appropriate sun angle.

The suggested sequences should be used for test scheduling purposes; however, they should not be interpreted as completely rigid. It is expected that occasions will occur when it is infeasible to conduct the next trial according to the schedule. For example, if the schedule calls for either a shadow or no-shadow trial of unlimited ceiling and there exists a real 6,000-foot ceiling, the Test Director should pass over the scheduled trial to the next feasible one. In such a case, the passed-over trial should be conducted as soon as possible; however, it is important that the designated crews fly their specifically assigned trial even when a trial is passed over.

d. Aircraft Crews

A total of eight crews (four for the F-4 and four for the A-7) are needed to fulfill the test objectives. To measure only the effects of the four controlled operational conditions upon measures of MAVERICK effectiveness within the test, it would be most efficient to use identical crews for all the scheduled trials. To utilize test results as an estimate of MAVERICK

capability, which is one of the principal objectives of this two-sided test, it is desirable to measure performance using as large a sample of TAC aircraft crews as possible. A larger number of crews not only assures more representative average results but also provides a means for determining the effect of the crew variability upon performance, which has proven to be a major factor in many previous aircraft weapon system tests. Therefore, as a minimum, four crews per aircraft type are called for in the test design. Each crew will fly an equal number of trials (11) and will be paired in four different combinations during the trials, as indicated in Table 4.

Table 4. ASSIGNMENT OF CREWS TO TRIALS

Team Designation	Crews in Team	No. of Trials
A	1 & 2	7
B	1 & 4	4
C	2 & 3	4
D	3 & 4	7

		C_1		C_2		C_3	
		B_1	B_2	B_1	B_2	B_1	B_2
S_1	G_1	A	B	C	D	A	D
	G_2	D	C	B	A	D	A
S_2	G_1	D	C	B	A	A	D
	G_2	A	B	C	D		

22 Trial Test

Only SBG and SCG confounded with crews; all main effects and first order (two-factor) interactions are clear as well as the three-factor interactions SBC and BCG.

The four crews have been carefully paired and assigned to trials in a systematic manner (as shown in Table 4) to ensure that the objectives of determining the effects of the controlled conditions on performance are not compromised. Therefore, the crew assignments for each trial condition must not be changed from that specified.

The use of more than one set of crews during the test presents a complication in the test design that is equivalent to adding a new controlled test variable to the test without increasing the number of trials. This can only be accomplished by confounding the differences among crews with some of the test variables or their interactions. This confounding effect has been minimized in this test design by having each of the four crews (for each type aircraft) fly the same number of sorties (1) at each level of a main test variable, (2) at each combination of two test variables, and (3) at some combinations of three test variables.

It is impossible to completely eliminate all confounding effects on interaction terms. For this test design, only the interaction effects from the combinations of all three test variables SBG and SCG will be confounded with the effects from crews. No confounding crew effects will occur for direct effects or for any interaction effects from combinations of two variables. Since only two crews (for each aircraft type) fly during any one trial, three crews cannot be integrated into the test design without making the unwarranted assumption that all interactions of the test variables are zero. This results from the fact that two crews flying during a trial provide comparisons from even numbers of test sorties (e.g., two sorties versus two sorties; four versus four; or eight versus eight). Such comparisons with three crews allocated among trials would find at least one crew member weighted an unequal number of times in the comparisons, thereby crew biasing the test results. Thus, the test design can accommodate four crews (the preferred condition) or two crews per type aircraft, but not three crews.

3. Discussion of Controlled Test Variables

a. Flight Ceiling

C_1 = *No ceiling restriction on operations.*

C_2 = *A weather ceiling that occurs with high frequency in the European theater.* The specific altitude band will be determined later from weather data. It will probably be in the vicinity of 4,000 to 6,000 feet.

C_3 = *A ceiling representing a practical minimum for operational employment of this weapon system.* This ceiling may represent operationally either a low ceiling condition or a constraint placed on the altitude of operations by the presence of SAMs in areas behind the combined arms unit.

The effect of ceiling can be simulated in the exercise with only minor artificialities. During the pretrial briefing, the pilots should be advised of the maximum (simulated) ceiling in the target area, and directed to conduct all operations accordingly. Data from any attack in which a MAVERICK event occurs above the specified altitude will be discarded as invalid.

Although both ceiling and visibility are important factors in weapon system performance, there does not appear to be any safe and accepted way of artificially simulating reductions in visibility below the ambient levels existing during the trials. Ambient visibility and illumination conditions will be recorded and any correlation with results that may be ascertainable will be reported. Both visibility and ambient illumination as such, however, will be uncontrolled variables in this operational exercise.[1]

[1] In the operational evaluation (described in Chapter II), it is planned to weight test results obtained under the test weather conditions to reflect the expected frequency of weather conditions in Europe. It is hoped that the relationship between contrast ratio, as affected by ambient illumination and visibility, and lock-on range can be obtained from MAVERICK test data currently being developed by the Air Force in Europe.

b. Shadow Condition

S_1 = *A test condition characterized by little or no shadows.* This condition may be controlled by choice of the time of day or by taking advantage of any days with heavy overcast.

S_2 = *A test condition characterized by distinct shadows such as created by bright sun and low angles providing strong cross-lighting.*

Several aspects of MAVERICK prelaunch performance, such as acquisition range, lock-on range, and proportion of launches at false targets, may be sensitive to shadow condition. Also, crews attempting to acquire and attack targets under different shadow conditions may find it desirable or necessary to fly different flight profiles, which could result in different vulnerability to the ground defenses.

On test days when there is sunshine, an S_2 trial could be conducted in early morning (commencing approximately 30 minutes after sunrise) or late afternoon (ending approximately 30 minutes before sunset) to ensure long shadow conditions; or an S_1 trial could be conducted during midday (approximately 1130 to 1330). If several days of overcast occur in the early phase of the test period, during which many of the S_1 trials can be completed, then sunny days that follow should be scheduled for completion of S_2 trials using appropriate periods in the early morning and late afternoon.

c. Terrain Clutter Background

B_1 = *Open terrain with scattered clumps of trees or distinct cultural features.*

B_2 = *Terrain with the greatest contrast in the amount of trees and distinct terrain features afforded by the test area.*

The degree of visual clutter may reflect upon prelaunch performance with respect to proportion of launches at false targets,

acquisition range, and difficulty of locking onto a selected target.

The test areas at Fort Riley that can be used to represent the two different conditions of terrain clutter background are described in Chapter V. In a general sense, the B_2 test areas can be classified as areas of moderate background clutter density and the B_1 test areas represent areas of low density background clutter. Both areas have some regions containing open terrain without trees and others with heavy foliage. Thus the particular terrain clutter condition that exists at the time of any particular simulated launch will depend on the location of the target array in the test area at that moment. Over the duration of a complete trial period, however, the percentage of time that background clutter occurs in the vicinity of the targets should differ considerably for the two different types of areas.

As described in Chapter V, there are three separate zones within the Fort Riley maneuver area that can be identified for each of the two types of terrain. This multiplicity of ground areas that the combined arms unit will traverse in successive trials should prevent the aircraft crews from quickly learning the terrain, and should thereby reduce the bias in the results from trials conducted late in the test program.

The use of three test zones to represent each terrain background condition and their RMS instrumentation coverage by use of mobile A-stations can present a problem in scheduling trials according to the suggested sequence unless care is exercised in selecting the order in which test zones are designated for use.

In order to provide adequate RMS coverage over the entire maneuver area, mobile A-stations must be moved between trials from one general test area to another (see Appendix A, Annex 3). The transfer itself and the recheck of equipment status may

require several hours. Therefore, it is suggested that when two trials are to be conducted during any one day, they be programmed to satisfy the combination of specified terrain background and scenario conditions at contiguous test zones that use most of the same mobile A-stations for ground coverage. By careful selection, it appears to be possible to accommodate any possible combinations of background and scenario for two sequential trials on the same day in contiguous test areas, without requiring major relocation of mobile A-stations between trials. (See Table 7 of Chapter V.)

d. <u>Ground Scenario</u>

G_1 = *An attack scenario in which an enemy combined arms unit is assaulting a defended friendly position.*

G_2 = *An exploitation scenario in which an enemy combined arms unit is attempting to exploit a breakthrough.*

It is planned to present two different scenarios for the situation on the ground requiring air support. The detailed delineation of these scenarios is presented in Chapter V. The primary differences between these scenarios as they may affect MAVERICK performance are:

<u>In the attack scenario</u>:

- MAVERICK aircraft will be operating in a close air support role where both enemy and friendly forces are in close proximity (i.e., within several kilometers of each other).
- A ground forward air controller (FAC), located in the vicinity of the U.S. defended position, will attempt to assist the aircraft crews in locating the target arrays.
- The armored vehicle array will be in attack formation.
- The general direction of approach of MAVERICK aircraft will be from the FEBA toward the approaching vehicles.

- SAMs are postulated behind the attacking ground units. Under situations where unlimited and medium ceiling restrictions are imposed, it is presumed that by a combination of suppression of the closest SAM units and reduction of engagement ranges of SAMs located farther to the rear by ECM techniques, the air up to and above the target area is clear of SAM threats for MAVERICK delivery aircraft. (That is, the only air defense threats to aircraft are the ADUs and SA-7s integral to the combined arms units.) Under low altitude ceiling restrictions, it is presumed that low altitude tactics are required to remain below the SAM engagement envelopes.[1] Appendix C, Chapter V, discusses these tactical situations in more detail.

In the exploitation scenario:

- The aircraft will be operating primarily against armored vehicles in column, moving as rapidly as possible to gain distance.
- The target array will not be in contact with friendly ground forces.
- No ground FAC will be available to assist in locating the target array (although an airborne FAC may be used).
- Aircraft can approach the target area from several different directions relative to the direction of movement of the armored vehicles, since aircraft are presumed to be operating in friendly territory without threat of SAMs.

For the test, 12 variations of each of the two scenarios have been developed (described in Chapter V). These variations relate each scenario to the six separately defined test areas (three for each terrain clutter condition).

4. Composition of a Test Trial

The composition of a test trial and the definitions of terms used are shown in Table 5. As indicated, a "trial" is represented by a distinct set of controlled test conditions ($S_i B_j C_k G_r$). In order to maintain approximately the same shadow condition (S_i) during any one trial, the duration of each trial should be limited to about 1 hour. This period coincides with the expected

[1]Aircraft tracks recorded during the test will be analyzed to assess potential exposure to ADU's outside the target array and to SAM's under the tactical situations postulated.

Table 5. COMPOSITION OF A TEST TRIAL

Term	Definition	No. Required
Trial	The tactical problem represented by a distinct set of controlled test conditions.	22 for the test
Test Sortie	Activity of a single aircraft during a trial (from wheels-up to wheels-down).	4 per trial
Attack	A sequence of aircraft passes during a test sortie in which a total load of MAVERICK weapons are launched (simulated). An attack, as defined here, represents a combat sortie.	3 per test sortie
Pass	Each distinct aircraft flightpath during an attack from roll-in through pull-out with the objective of engaging at least one ground target.	Footnote a
Simulated Launch	The trigger action that simulates launch of a MAVERICK missile against a target that has been locked onto.	4 or 6 per attack, whichever represents the weapons load

[a]The number of passes in each attack will depend on the weapon delivery tactics and the trial conditions.

time that an F-4 based at McConnell AFB could operate in the target area. The trial period is also constrained by the MAVERICK video tape recording limitation in the aircraft--approximately 25 minutes. Since the video records only when the MAVERICK is activated (approximately 1 minute each pass), at least 15 attempted launch passes could be recorded per trial. This is adequate to meet the test design requirements.[1]

[1]The ADU boresight camera film capacity and exposure rate may also limit trial periods.

In order to ensure availability of four aircraft per trial during the test, it is suggested that an average of three trials be scheduled every 2 days. The test program is designed for a maximum of two trials per test day. When more than one trial is to be conducted on the same day, the trials should be sufficiently spaced in time such that the ground units can be relocated between trials to present a different ground situation (terrain background or scenario variation), and for the aircraft to return to McConnell for refueling between trials.

a. Test Sorties and Constraints on Participating Aircraft

A test sortie consists of an aircraft proceeding to the designated target area and under the specified ceiling condition making three attacks against the target array in the area. Two F-4 test sorties and two A-7 test sorties are required for each trial (i.e., against each tactical situation). Although the aircraft type has not been designated as a controlled variable, it becomes one when two types are used, even though the factorial design is not affected. Performance data will be differentiated by aircraft type and analyzed to determine any significant differences that can be attributed to this factor.

Consistent with the philosophy of "free play," the test design prescribes neither the number of aircraft in a single flight at any one time during a trial nor the tactics to be employed. These will be determined by the Air Force based on the use of appropriate tactics and numbers of aircraft for the particular tactical situation posed by the trial.

In summary, the only constraints placed on participating aircraft by the test design are:

- Each trial consists of at least two F-4 and two A-7 test sorties.[1]

[1] If during a trial only one F-4 or A-7 is available, the trial could be conducted and the reduced (continued on next page)

- Each test sortie consists of at least three attacks.
- All aircraft participating in the test carry appropriate instrumentation (described in Appendix A).
- Only MAVERICK-equipped aircraft be employed in passes against the ground target array during an attack.

With respect to the last item, since in combat aircraft might normally carry a mixed weapons load rather than a full load of MAVERICKs, the use of non-MAVERICK aircraft to simulate aircraft with other air-to-ground weapons has been considered. By DDR&E direction, however, this two-sided test and evaluation is restricted to MAVERICK-related performance. The use of any aircraft in the test simulating employment of other weapons would serve only to complicate unnecessarily the data collection and analysis of performance; and either would compound the scope of the test program without providing additional performance data or would dilute the amount of performance data for the same test effort.

b. Attacks

A simulated combat sortie has been designated in this test as an "attack" to avoid confusion with the term "test sortie" used above. Each aircraft attack consists of a MAVERICK aircraft arriving in the target area and making a sequence of passes and simulated MAVERICK launches at the target array until it has simulated launch of its entire weapons load. Between attacks, the aircraft separates itself from the vicinity of the target array and after a suitable interval of time

(cont'd) data sample under that set of conditions accommodated in the post-trial analysis; however, it should be recognized that the test is designed for each set of conditions to be represented only once. Therefore, flying less than two aircraft of a type during a trial not only degrades the sample size for that condition, but also prevents any measure of crew variability for that type aircraft under the trial condition. More than one or two such occurrences could destroy the effectiveness of the test as designed.

reapproaches the test area and initiates another attack. It is not intended to specify the exact procedure herein, but merely to outline the objective. It is desired that the procedure used to separate attacks be planned to minimize the amount of learning carried over from the previous attack to the first pass of the subsequent attack (i.e., to the extent possible, consecutive attacks should be designed to simulate independent combat sorties under the same tactical situation). To maintain an approximate replication of the ground situation from one attack to another during a trial requires that the ground target array regroup prior to the beginning of each new attack. The guidelines for ground unit activity during a trial are described in the scenario section of Chapter V.

At least three attacks should be conducted during each test sortie to provide a sufficient number of independent observations of attack events. This number provides minimum desired precision in measuring significant differences in performance caused by variations of controlled variables.

An attack (i.e., expenditure of a weapons load) has been selected in the test design as the basic normalizing factor. That is, all data will be grouped into units of attacks. This normalizing factor is the only one for which aircraft exposure to air defense weapons can be meaningfully associated. The number of passes required to expend the weapons load, which is a necessary input to the analysis of aircraft attrition during missions, can be derived only by having passes grouped in attack units.

Analysis of events during an attack on a prelaunch and per-pass basis will also be accomplished in the analysis. For the highest level of aggregated results, however, selection of any normalizing interval less than an attack does not provide for independent observations. For example, what happens on the second or subsequent passes is not necessarily independent of

what happened on the first pass. By the selection of "attack" as the basic normalizing factor in the test design, all of the events involved with aircraft exposure and prelaunch performance can be operationally related.

The first three attacks during a trial will be performed under the basic test conditions and provide the replications in the test design against which to measure the average differences between the controlled variables. This much of a trial must be successfully performed.

If there is sufficient fuel, video tape time, aircraft still camera film, and ADU boresite camera film for more attacks than the required three, then these attacks, if desired, could be used to measure differences in performance that might result from utilization of different air tactics.[1] Some examples of possible variations in tactics that might be explored by these means are:

- Flying a mission using tactics (other than altitude) based on the assumption that SAMs are a threat, versus no SAMs or suppressed SAMs.
- Attacking the target array as an element of two aircraft versus a flight of four.
- Approaching the battle area at reduced speed in an attempt to maximize first pass acquisition range.
- Single versus multiple launches per pass.

If it is decided to introduce any of the above controlled tactics variations into the test, the specific choice(s) should be selected prior to the test and incorporated into the test plan.

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[1]The basic air tactics to be used will be selected by TAC as optimal for the particular tactical situation presented. The development of MAVERICK tactics is one of the principal objectives of COMBAT HUNTER Phase II.

Chapter V

FORT RILEY AND THE TEST SCENARIOS

This chapter describes briefly Fort Riley and the areas in which the test scenarios will be staged. Detailed test scenarios are presented that transfer the action of the European scenarios in Appendix C to the Fort Riley area.

A. FORT RILEY TEST AREA

Fort Riley, Kansas, was recommended[1] by a specially designated test site selection committee as the military reservation in the U.S. most representative of the type European terrain on which tank combat might occur, and which could accommodate the MAVERICK two-sided test; it was approved as the sole test site for the MAVERICK joint two-sided test.[2]

Fort Riley is the home station of the 1st Infantry Division (Mechanized) and contains three tank battalions equipped with M-60 tanks and one air defense battalion equipped with the Vulcan/Chapparal. The total usable maneuver area is approximately 70,000 acres. The terrain consists of rolling plains bordered on the south and southwest by the Republican River and the Milford Reservoir, and on the southeast by the Kansas River.

The nearby airfields include Marshall Army Airfield, Manhattan Municipal Airport, and McConnel AFB. Marshall Army

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[1] WSEG Memorandum to DepDDR&E(T&E), "MAVERICK Test-Site Selection Survey 9-12 August 1971," 19 August 1971.

[2] DDR&E(T&E) Memorandum dated 12 October 1971. Subject: Site Selection for COMBAT HUNTER Phase III.

Airfield is located in the southern part of the reservation, has a 4,500-foot runway, and can handle C-131-type aircraft. Manhattan Municipal Airport has a 5,500-foot runway and can handle Boeing 727s. McConnel AFB is located at Wichita, 95 miles away, and can support TAC aircraft. At Marshall Army Airfield, an Air Force Weather Detachment is assigned and the organic aircraft of the 1st Infantry Division (Mechanized) are based; consequently, normal aircraft maintenance and POL are available. The tower and weather forecast service are operated from 0700 to 2300 hours weekdays, from 0700 to 1900 hours Saturdays, from 1000 to 1800 hours Sundays, and closed on holidays.

The maneuver area planned for the two-sided MAVERICK test is located in the northwest quadrant of Fort Riley (Figure 3). It is bounded by old U.S. Highway 77 on the east, Kansas State Highway 82 on the south, and the Military Reservation Boundary on the west and north. It consists of an area 11 kilometers east and west by approximately 8 kilometers north and south. This maneuver area excludes the firing and target positions of the tank gunnery range. Three well defined creek beds pass through this area from north to south with numerous draws and defiles providing watershed down to the creek beds. The elevation ranges from a high of approximately 1,360 feet MSL to 1,150 feet in one of the creek beds. In May and June, the terrain is covered with green vegetation and the deciduous trees and bushes are in full foliage. There are numerous farm buildings and silos located throughout the area.

The soils in the field exercise area are of the loam type, although there is some clay underlain with calcareous shale or limestone and an overlay of loess soils of medium to heavy thickness. Soils vary from low tractive efficiency (slippery when wet) to excellent. The soil dries rapidly for the most part and, unless there is an excessive amount of moisture, the trafficability returns to normal within a day or two. During early spring, the soil trafficability varies from excellent to

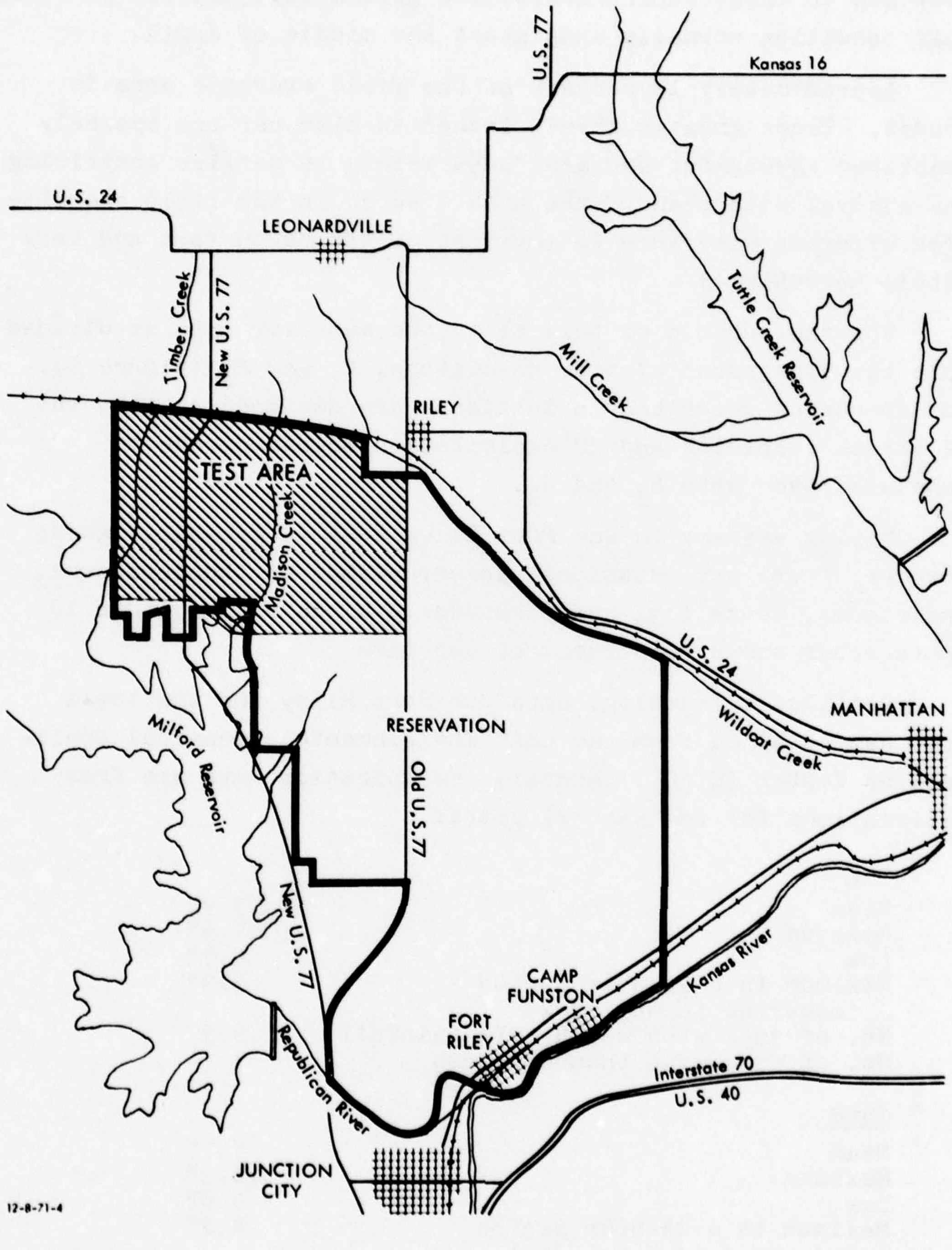

Figure 3. FORT RILEY AREA

poor due to frost, which leaves the ground soft and wet at times; this condition normally ends about the middle of April.

Approximately 15 percent of the field exercise area is wooded. Trees greater than 3 inches in diameter are sparsely scattered throughout and are found mainly in defiles comprising the natural watershed of the area. Woods in the field exercise area offer no hindrance to movement of troops on foot and very little to vehicles.

For the purpose of this test, the maneuver area is divided into two background clutter conditions, B_1 and B_2 (Figure 4). The scenarios described in Section C are designed so that t[illegible] 12 attack scenarios and 12 exploitation scenarios can be scheduled over both B_1 and B_2.

Flying weather in the Fort Riley area is generally good; however, there are occasional interruptions by thunderstorms, hailstorms, dense fog, and tornadoes. Winds of less than 10 knots occur about 70 percent of the time.

Detailed climatology data for Fort Riley and the local area was obtained from the USAF Environmental Technical Applications Center (ETAC). Monthly precipitation data are from observations for the past 21 years:

<u>May</u>

Mean	3.9"
Maximum	7.9"
Low	0.9"
Maximum in a 24-hour period (occurred in May 1962)	3.9"
No. of days with measurable rainfall	9.3
No. of days with thunderstorms	7

<u>June</u>

Mean	5.7"
Maximum	10.3"
Low	0.8"
Maximum in a 24-hour period (occurred in June 1963)	4.2"
No. of days with measurable rainfall	11.7
No. of days with thunderstorms	10.5

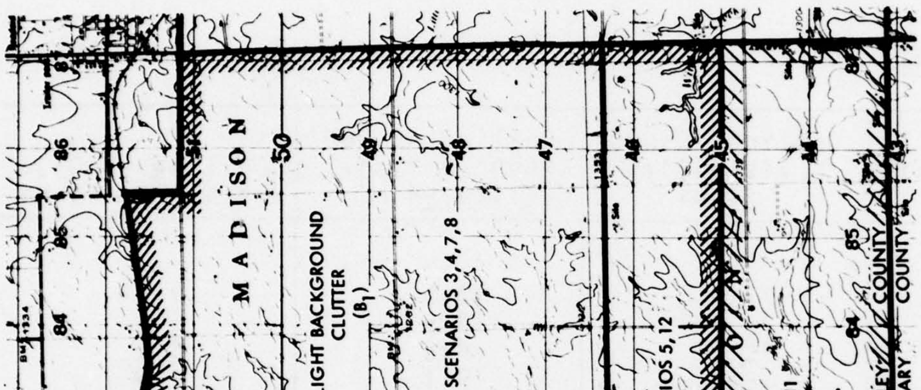

Figure 4. TEST AREA

The percentage frequency of occurrence of climatological conditions for each hour of the day are shown in Table 6, which was derived from data obtained from observations for the 10-year period 1958-1968.

Table 6. PERCENTAGE FREQUENCY OF CLIMATOLOGICAL CONDITIONS

Local Std Time	Ceiling ≥5,000' & Visibility ≥4 mi	Ceiling <5,000' ≥500' & Visibility ≥4 mi	Ceiling <500' & Visibility <4 mi
May			
0600	77.1	13.5	9.4
0700	79.7	13.5	6.8
0800	79.0	14.8	6.2
0900	78.4	17.1	4.5
1000	76.8	19.7	3.5
1100	75.5	19.0	5.5
1200	74.2	21.9	3.9
1300	76.5	20.0	3.5
1400	74.5	21.3	4.2
1500	77.7	19.0	3.3
1600	78.1	19.0	2.9
1700	81.3	15.5	3.2
1800	85.5	11.9	2.6
1900	86.1	11.0	2.9
2000	85.2	11.6	3.2
June			
0600	83.0	10.0	7.0
0700	81.0	13.0	6.0
0800	81.3	14.3	4.4
0900	82.0	15.0	3.0
1000	83.7	13.3	3.0
1100	83.3	16.0	0.7
1200	82.0	16.7	1.3
1300	83.0	16.0	1.0
1400	81.3	18.0	0.7
1500	82.7	16.7	0.6
1600	84.0	15.3	0.7
1700	87.3	11.7	1.0
1800	90.3	9.0	0.7
1900	92.0	6.3	1.7
2000	91.0	8.0	1.0

B. SPECIAL TRAINING REQUIREMENTS

In order to have the most realistic operational environment possible, it is necessary that the Army unit tasked to provide the Soviet ground array be thoroughly trained in Soviet tactics and techniques. It is particularly important that the air defense units be trained to use techniques of acquisition, tracking, and firing that approximate Soviet usage as closely as the equipment used will permit. Armored ground elements should use formations, frontages, and tactical maneuvers that are consistent with current Soviet doctrine. This doctrine is described in Appendix C.

C. TEST SCENARIOS

1. General

The test scenarios to be used are derived from several U.S. Army Combat Development Command studies and experiments, primarily the Army Direct Aerial Fire Support Systems Study and the USA CDC Experimentation Command Experiment 43.6, Attack Helicopter Daylight Defense. These scenarios present potential Western European situations in the 1975 time frame applicable to the MAVERICK operational test and evaluation objectives. Two types of situations are depicted: a Soviet attack of a defended position in the Fulda Gap region of West Germany (attack scenario G_1) and a Soviet exploitation in the North German Plain (exploitation scenario G_2). These scenarios are used to represent operational ground situations that may have significantly different effects on MAVERICK performance. Appendix C discusses the assumed scenarios in the European theater and the Soviet operating procedures and weapon characteristics; this section is a translation of these scenarios to Fort Riley for the MAVERICK two-sided test.

The European scenarios are translated to Fort Riley by assigning frontages and road space (consistent with the

hypothetical situations) to the actual player units on the maneuver areas. Twelve variations of both scenarios have been developed so that they can be staged in several different test areas.

In all situations, the attacking unit is a company of the 1st Tank Regiment, which is attacking with the 1st and 2nd Battalions. Each variation of both scenarios is identified by an objective number in the maps that follow. In the attack scenario, the objective is the end point while the exploitation scenario begins at the objective.

The scenarios illustrated give only the broad operational concept. For each scenario, the specific details should be based on a thorough ground reconnaissance. Attack scenarios should be staged using the following guidelines:

- Initial unit locations should be such that the attacking force must traverse approximately 3 kilometers before reaching the defended position.
- Defending forces should be withdrawn when attackers approach within approximately 500 meters of the defensive position.
- Subsequent defensive positions should be 2 to 3 kilometers behind the previous position.
- The last defended position should be the objective area.
- The attacking force should maintain the appropriate attack formations and speeds as specified in Chapter IIC of Appendix C.[1]
- The opposing forces should use the standard tactical doctrine as specified by the U.S. Army for the defending force and by the USSR for the attacking force.

2. Classification and Scheduling of Scenarios

Table 7 shows the classification of scenarios by the type of background clutter associated with the area of action. A

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[1]Formations and speeds appropriate for units in the exploitation scenarios are specified in Chapter III of Appendix C.

Table 7. CLASSIFICATION OF SCENARIOS BY BACKGROUND CLUTTER

Background Clutter Condition	Attack Scenario (G_1) No.	Exploitation Scenario (G_2) No.
B_1	A3, A4, A5, A7, A8, A12	E3, E4, E5, E7, E8, E12
B_2	A1, A2, A6, A9, A10, A11	E1, E2, E6, E9, E10, E11

detailed description of each numbered scenario variation follows in Subsections 3 and 4. The base of 12 variations of each type scenario provides sufficient flexibility of scheduling to permit minimum movement of mobile A-stations between trials without successive trials being run over the same ground. Table 8 lists the possible scenario variations that can be used when sequential trials require the combination of terrain clutter and type scenario shown.

3. Attack Scenario G_1[1]

Variations in the attack scenarios are presented in the following paragraphs.

a. First Tank Regiment Attack to the North (A1, A2, A3, and A4)

The 1st Guards Tank Division, having seized crossing of the Republican and Kansas Rivers, is attacking to the north to secure the area between Milford and Tuttle Creek Reservoirs (Figure 5). The 1st Tank Regiment is attacking on the left to seize the high ground north and west of Leonardville. The two lead battalions are attacking with all companies abreast (Figure 6). U.S. Task

[1]The textual references to Figures 5 through 19, which portray pictorially the scenario situations at Fort Riley, are presented at the end of this chapter.

Table 8. ACCEPTABLE SCENARIO VARIATIONS[a] FOR ALL POSSIBLE COMBINATIONS OF TERRAIN BACKGROUND AND SCENARIOS IN SUCCESSIVE TRIALS

Possible Sequence of Trial Combinations		Acceptable Scenario Numbers[a]		Possible Sequence of Trial Combinations		Acceptable Scenario Numbers[a]	
1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial	1st Trial	2nd Trial
B_1G_1	B_1G_1	A3 or A8 A4 or A7	A4 or A7 A3 or A8	B_2G_1	B_1G_1	A5 or A12 A6 or A11	A6 or A11 A5 or A12
	B_1G_2	A3 or A8 A4 or A7	E4 or E7 E3 or E8		B_1G_2	A5 or A12 A6 or A11	E6 or E11 E5 or E12
	B_2G_1	A5 or A12 A6 or A11	A6 or A11 A5 or A12		B_2G_1	A1 or A10 A2 or A9	A2 or A9 A1 or A10
	B_2G_2	A5 or A12 A6 or A11	E6 or E11 E5 or E12		B_2G_2	A1 or A10 A2 or A9	E2 or E9 E1 or E10
B_1G_2	B_1G_1	E3 or E8 E4 or E7	A4 or A7 A3 or A8	B_2G_2	B_1G_1	E5 or E12 E6 or E11	A6 or A11 A5 or A12
	B_1G_2	E3 or E8 E4 or E7	E4 or E7 E3 or E8		B_1G_2	E5 or E11 E6 or E11	E6 or E11 E5 or E12
	B_2G_1	E5 or E12 E6 or E11	A6 or A11 A5 or A12		B_2G_1	E1 or E10 E2 or E9	A2 or A9 A1 or A10
	B_2G_2	E5 or E12 E6 or E11	E6 or E11 E5 or E12		B_2G_2	E1 or E10 E2 or E9	E2 or E9 E1 or E10

[a]To minimize requirements to move A-stations between trials.

Force 1/63 Armor is defending as shown on Figure 7. This regiment attack is identified by the objective numbers of Figure 6. The two middle attacks are not used because of interference of the gunnery range at Fort Riley.

b. First Tank Regiment Attack to the South (A7, A8, A9, and A10

The 1st Guards Tank Division is attacking south to seize crossings of the Republican and Kansas Rivers in the vicinity of Junction City and Manhattan (Figure 8). The 1st Tank Regiment is on the right (west) and has the mission of crossing the Republican River and seizing Junction City and the high ground to the south of the Republican and Kansas Rivers. The two lead battalions are attacking with all companies abreast (Figure 9). U.S. Task Force 1/63 Armor is defending with initial positions as shown on Figure 10. This regimental attack is identified by the objective numbers on Figure 9. The two center attacks are not used because of the tank gunnery range interference.

c. First Tank Regiment Attack to the East (A5 and A6)

The 1st Guards Tank Division is attacking to the east to seize crossing of the Kansas and Big Blue Rivers in the vicinity of Manhattan (Figure 11). The 1st Tank Regiment is on the right (south) with the mission of seizing the Kansas River bridge at Manhattan and securing the high ground south and east of Manhattan. The attacking battalions each have two companies abreast and one in reserve (Figure 12). U.S. Task Force 1/63 Armor is defending with initial positions as shown on Figure 13. This regimental attack is identified by the objective numbers of Figure 12. The northern battalion attack is not used because of the gunnery range.

d. First Tank Regiment Attack to the West (A11 and A12)

The 1st Guards Tank Division is attacking to the west to secure the area between Milford and Tuttle Creek Reservoirs. (Figure 14). First Tank Regiment is on the left (south) with the mission to seize the high ground west of Timber Creek and north of Milford Reservoir. The lead battalions are attacking with two companies leading and one in reserve (Figure 15). U.S. Task Force 1/63 Armor is defending with initial positions as shown on Figure 16. This regimental attack is identified by objective numbers on Figure 15. The northern battalion attack is not used because of the gunnery range.

4. Exploitation Scenario G_2

The exploitation scenario as described in Appendix C cannot be directly related to a tactical situation in the assigned maneuver area because the constraints of the area do not allow sufficient room to depict a realistic ground scheme and, at the same time, keep the unit in an area of desired background clutter. Therefore, exploitation routes have been selected to provide a trace that will retain the unit in the desired area and will permit the unit to assume a realistic exploitation formation (i.e., a column). Twelve routes are shown in Figures 17, 18, and 19 that can be used to provide the exploitation ground scenarios necessary to fulfill the requirements of the test design.

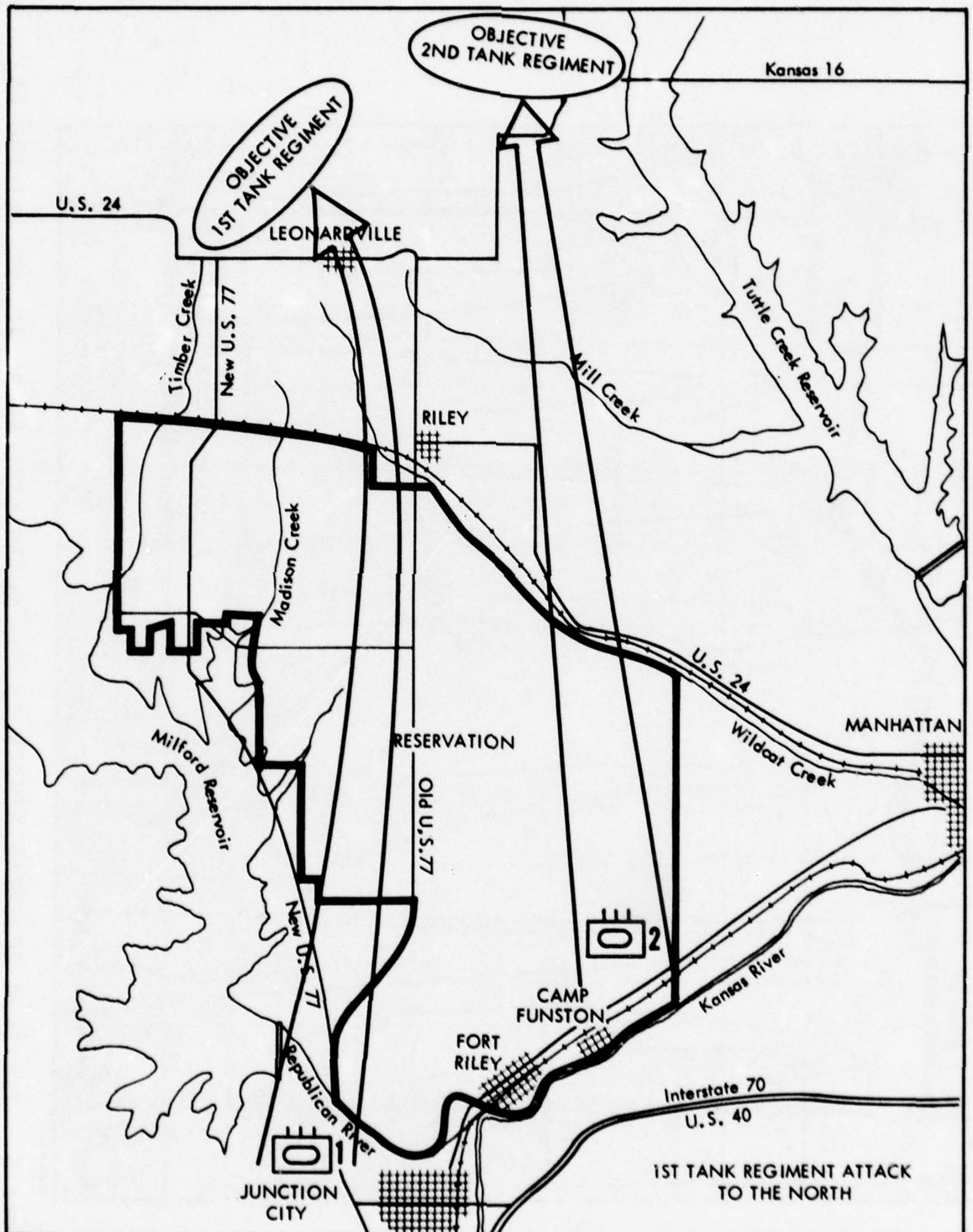

Figure 5. 1st TANK REGIMENT ATTACK TO THE NORTH

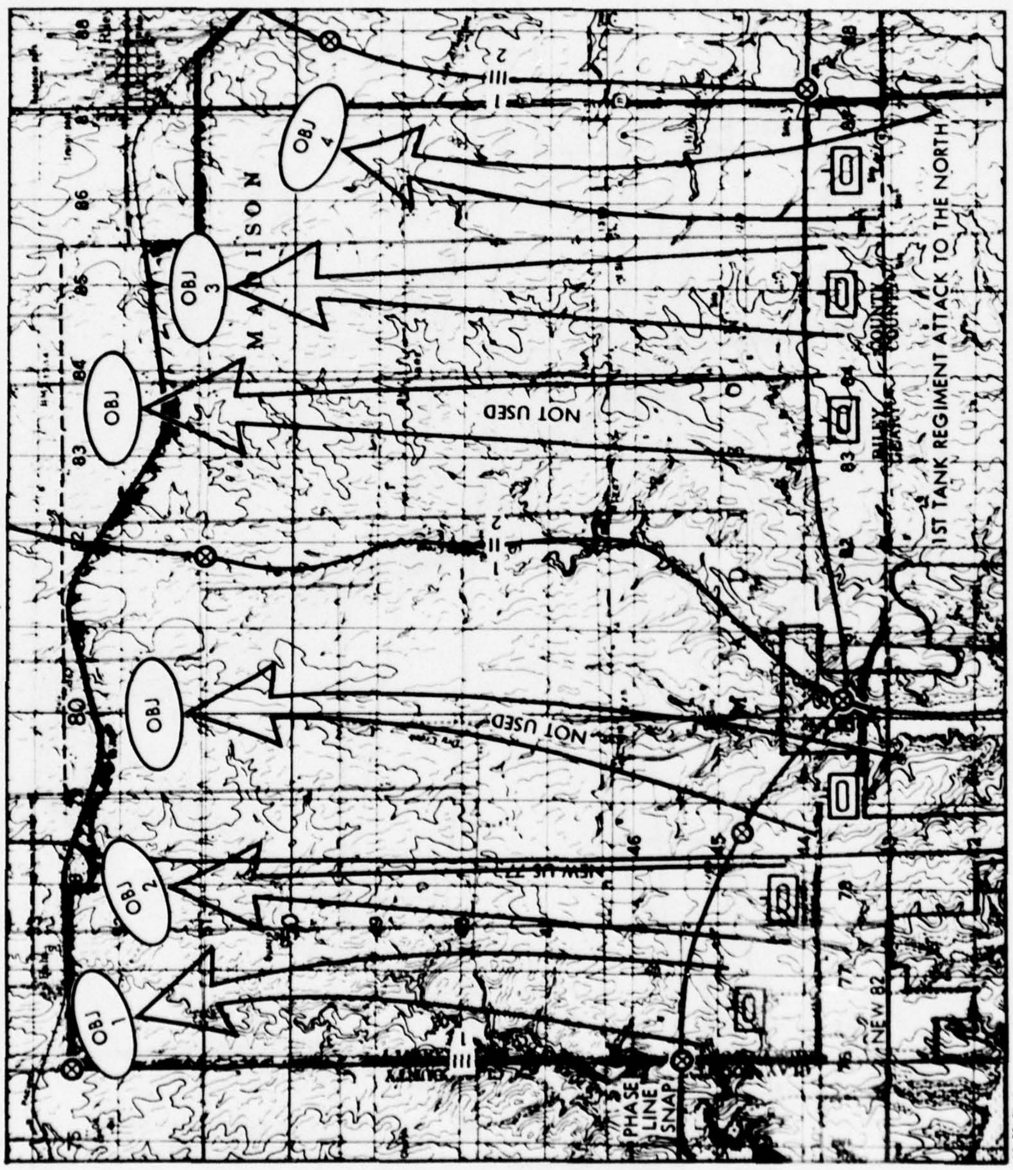

Figure 6. 1st TANK REGIMENT ATTACK TO THE NORTH (SCENARIOS A1, A2, A3 AND A4)

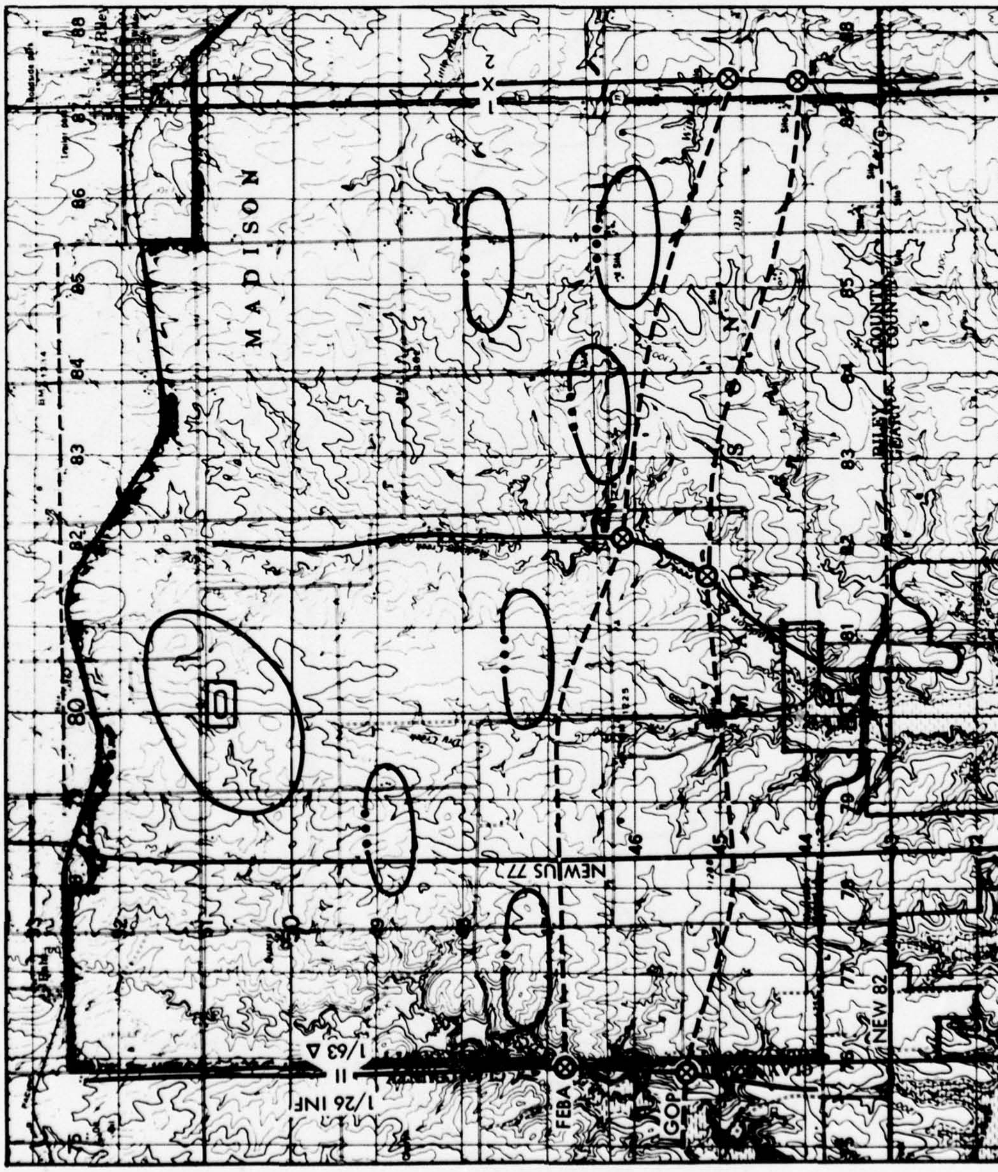

Figure 7. U.S. FORCES DEFENDING FACING SOUTH

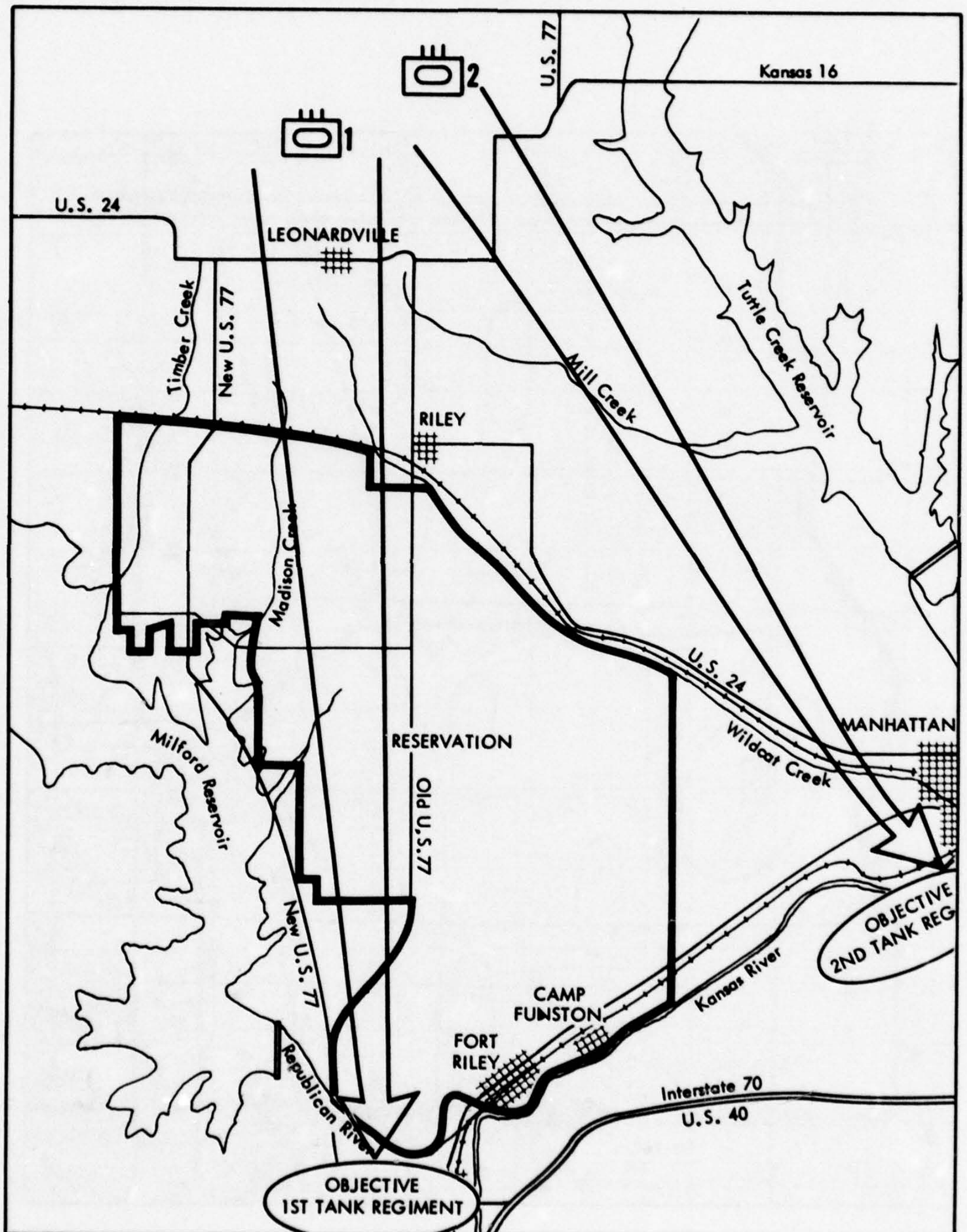

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Figure 8. 1st TANK REGIMENT ATTACK TO THE SOUTH

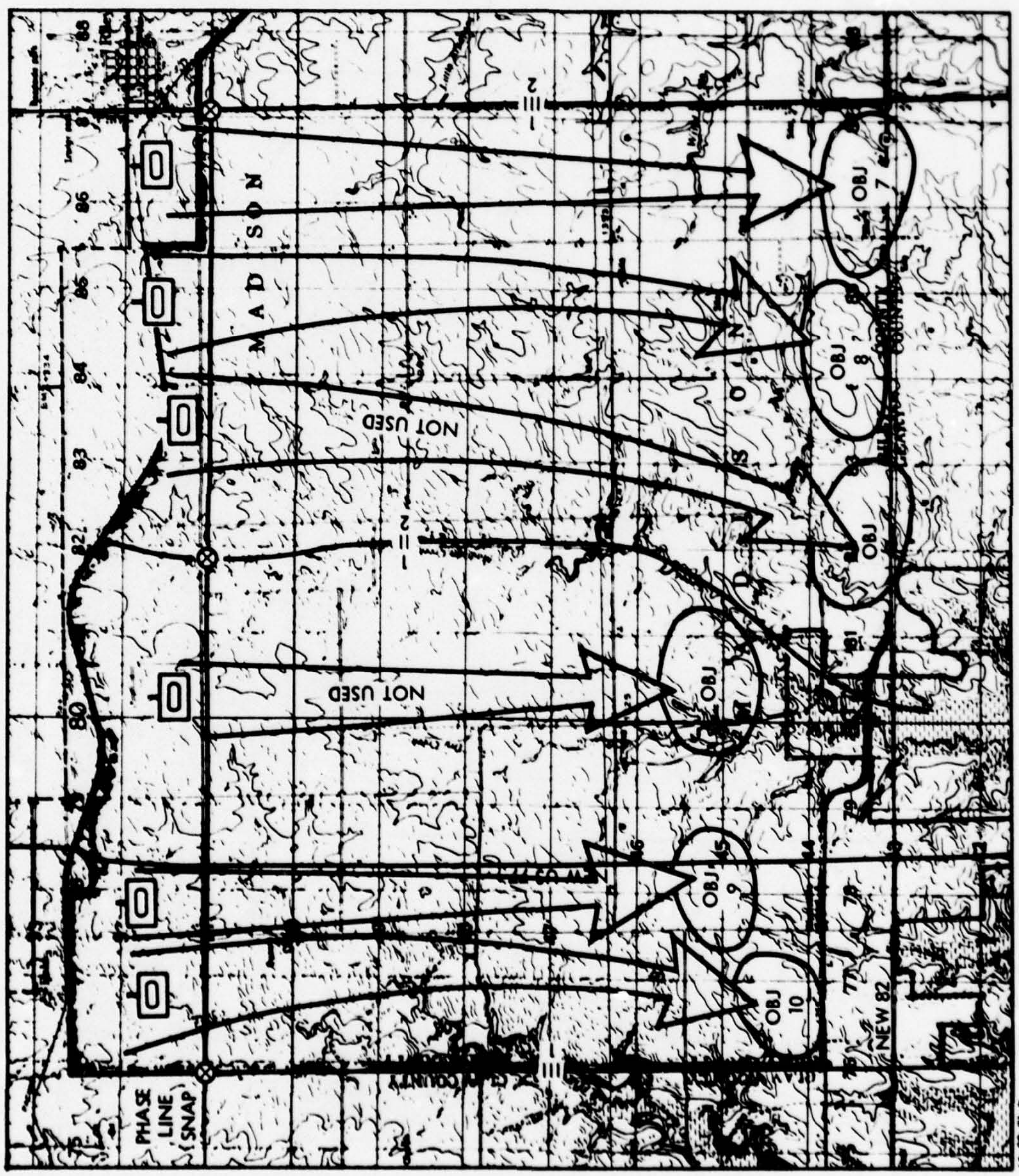


Figure 9. 1st TANK REGIMENT ATTACK TO THE SOUTH (SCENARIOS A7, A8, A9 AND A10)

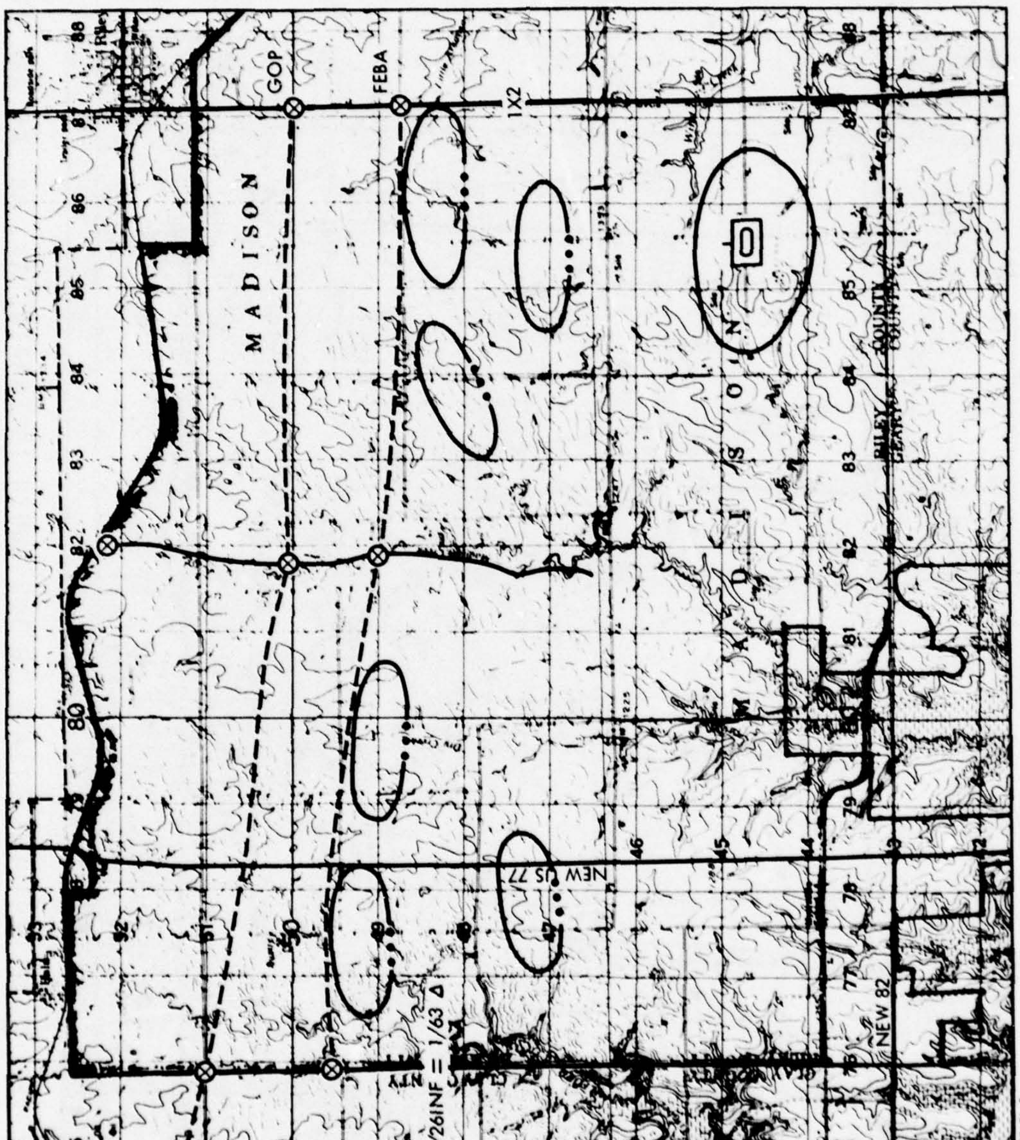
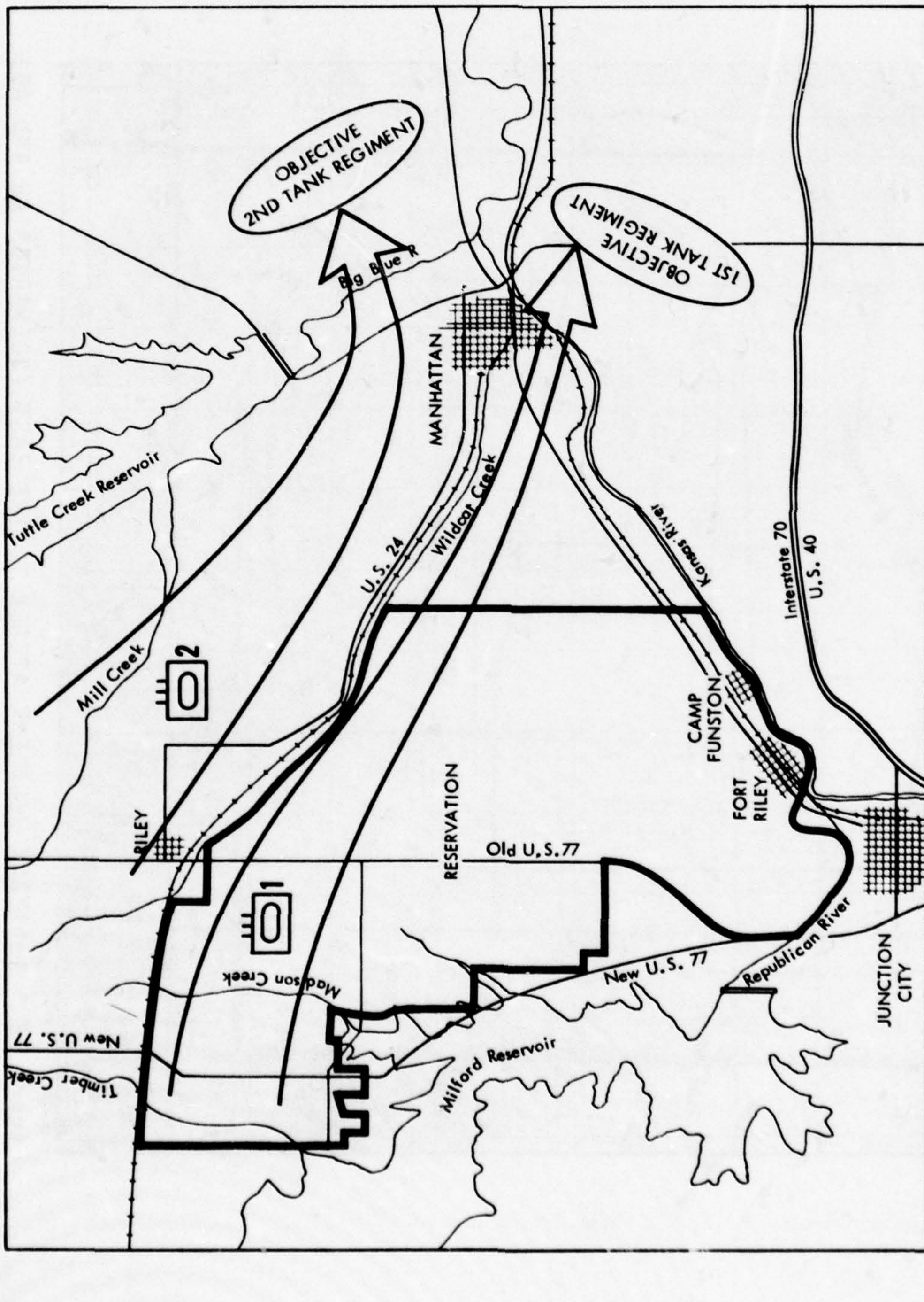


Figure 10. U.S. FORCES DEFENDING FACING NORTH



12-22-71-3

Figure 11. 1st TANK REGIMENT ATTACK TO THE EAST

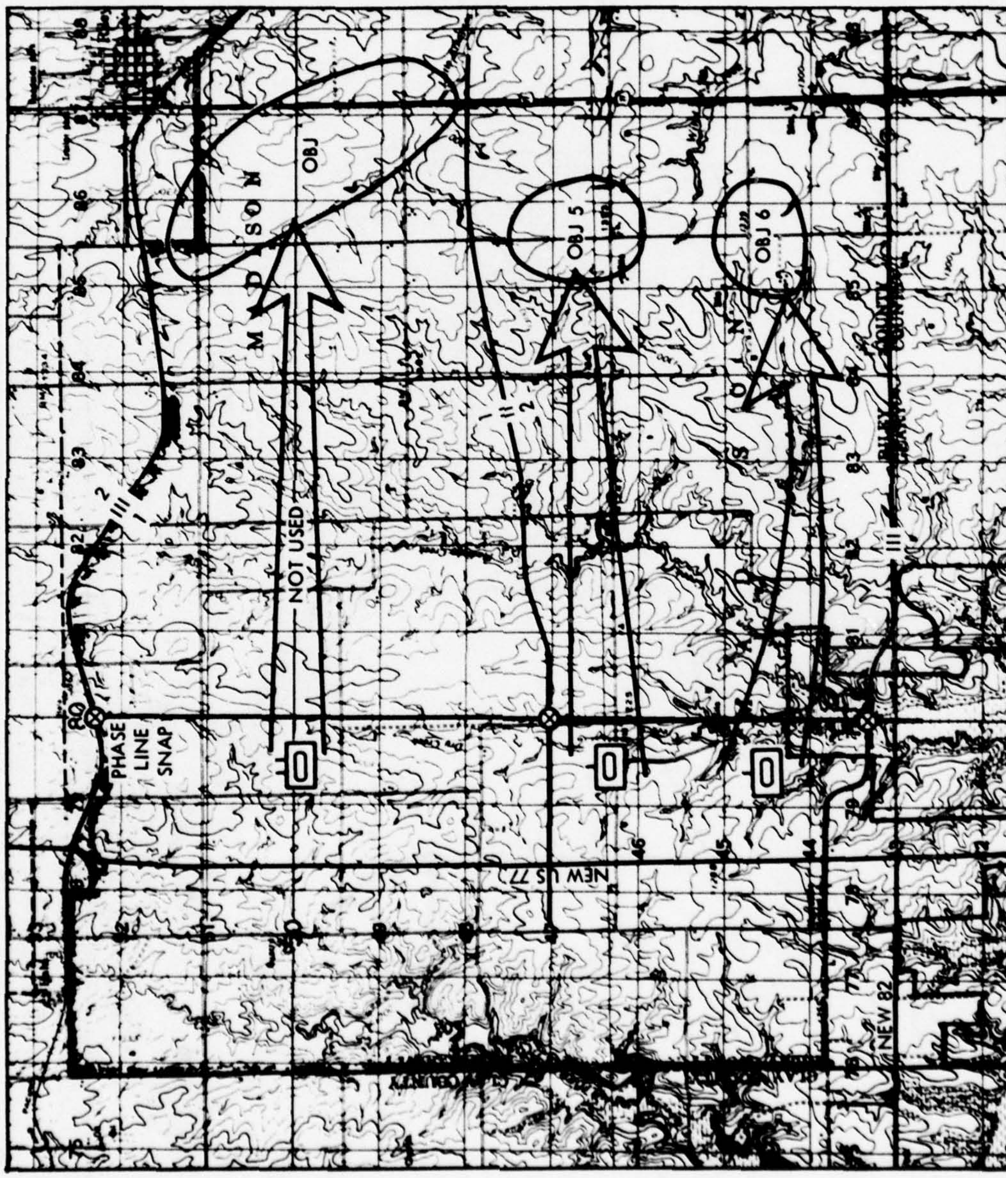


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Figure 12. 1st TANK REGIMENT ATTACK TO THE EAST (SCENARIOS A5 AND A6)

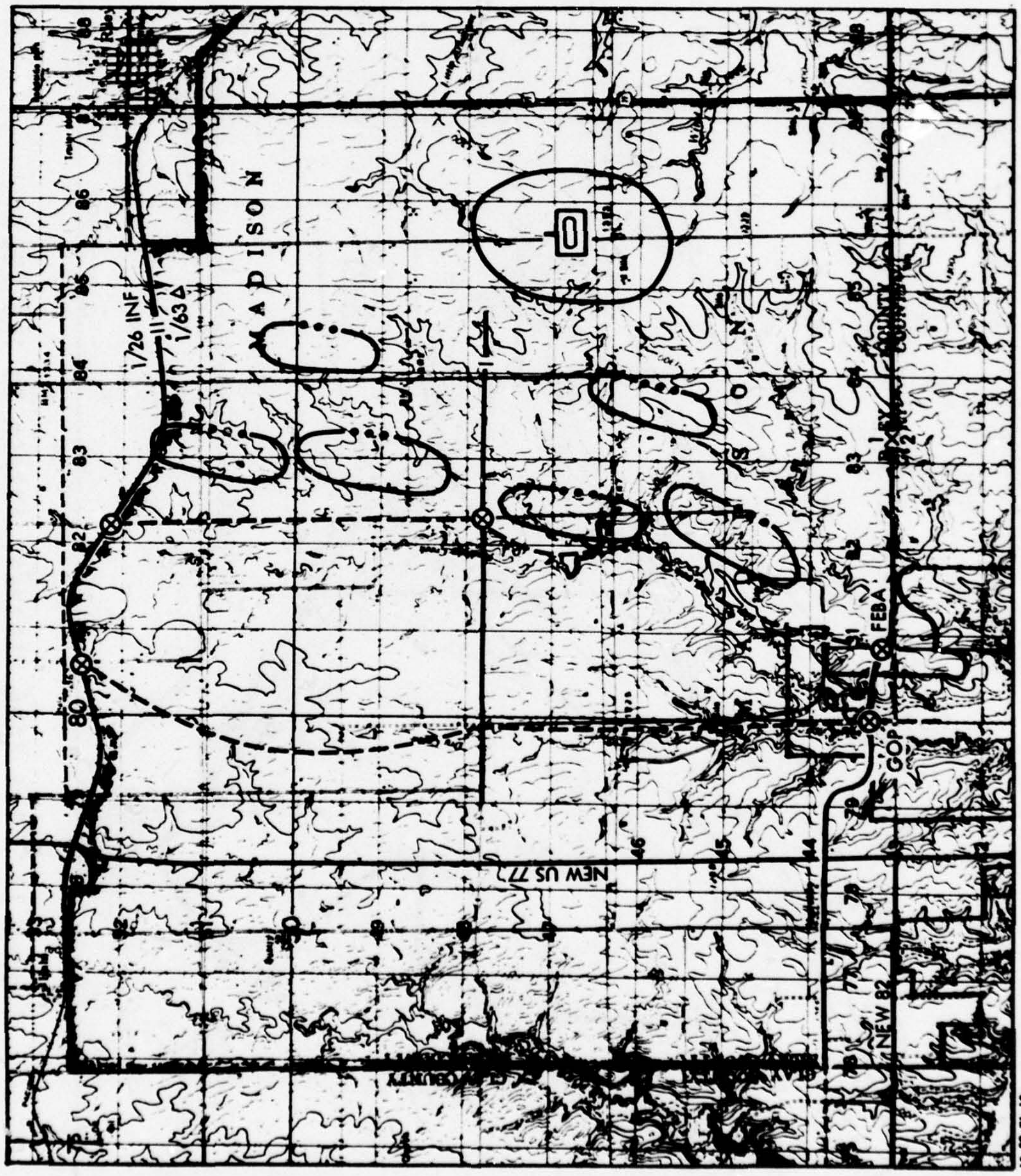

Figure 13. U.S. FORCES DEFENDING FACING WEST

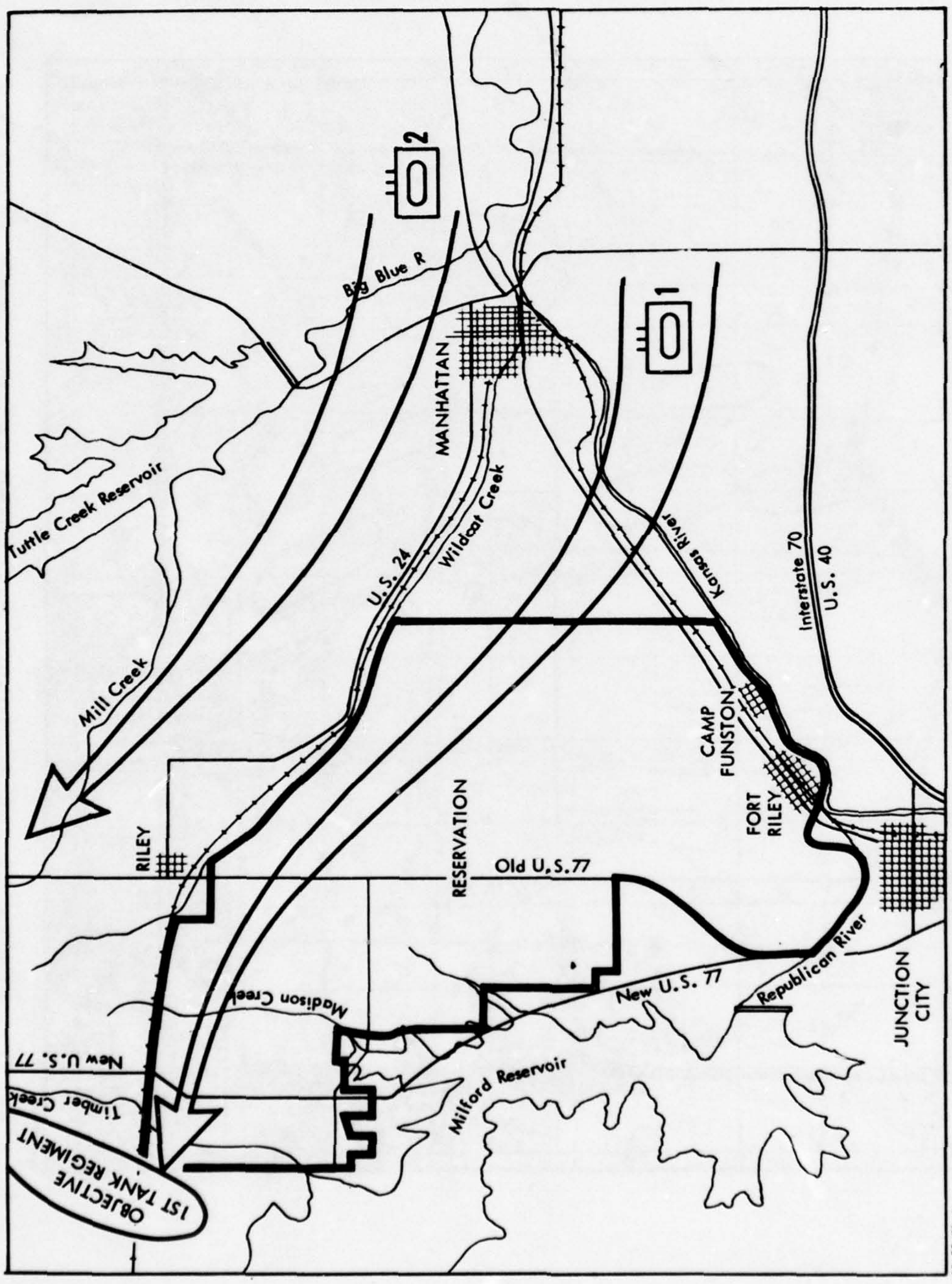

Figure 14. 1st TANK REGIMENT ATTACK TO THE WEST

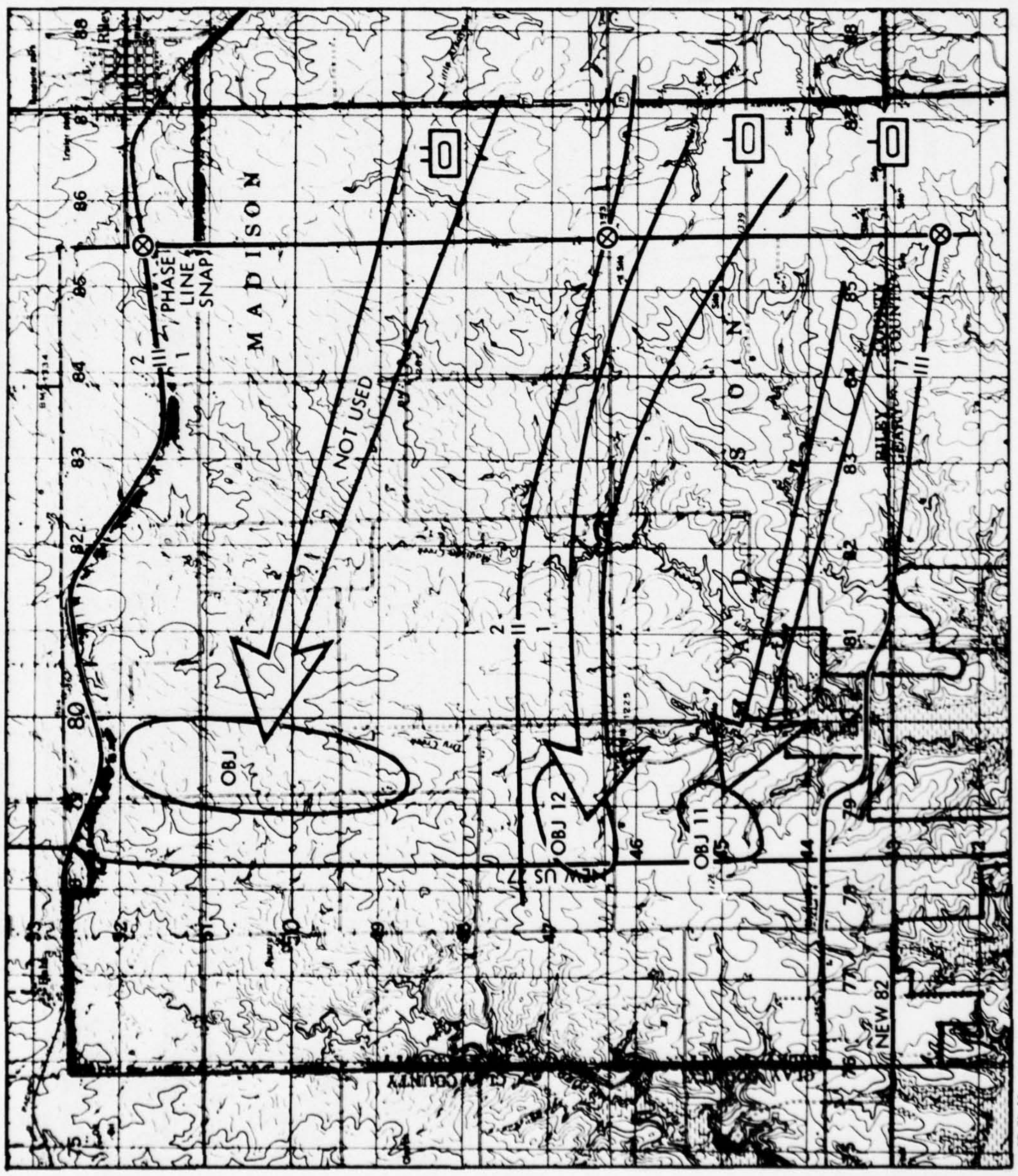

Figure 15. 1st TANK REGIMENT ATTACK TO THE WEST (SCENARIOS A11 AND A12)

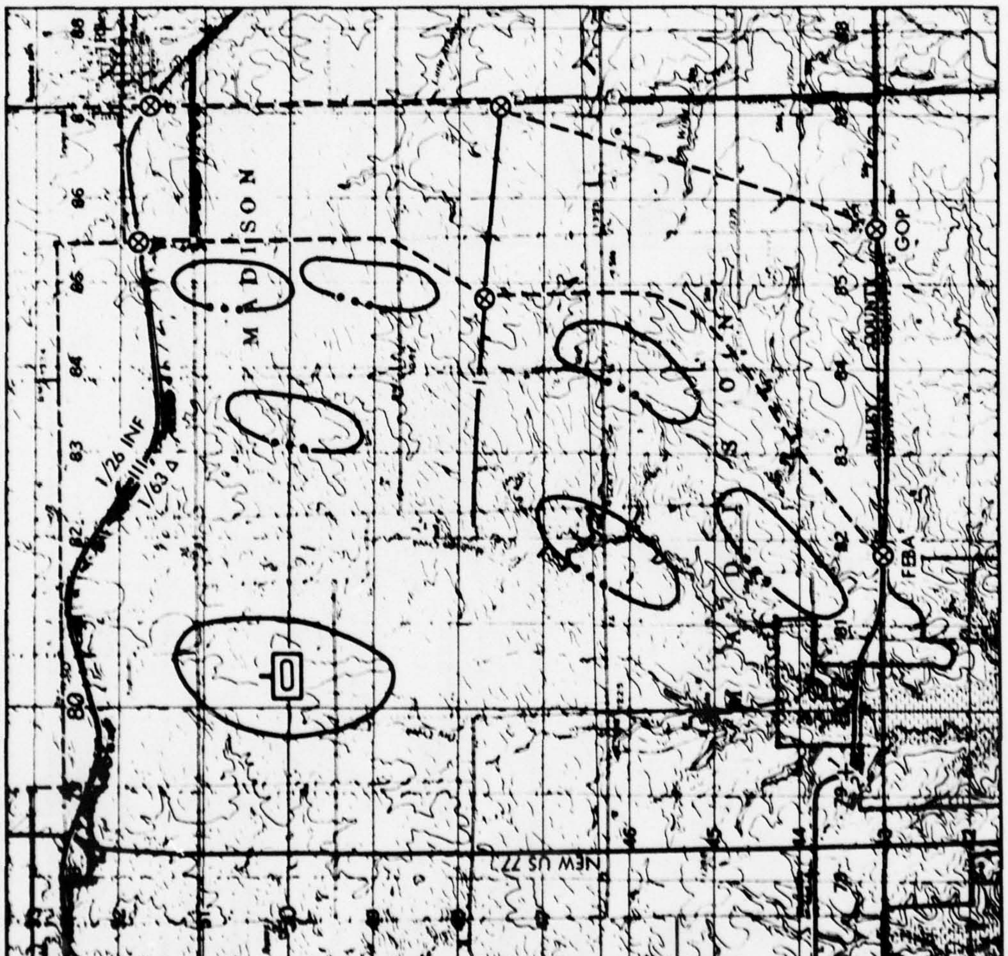

Figure 16. U.S. FORCES DEFENDING FACING EAST

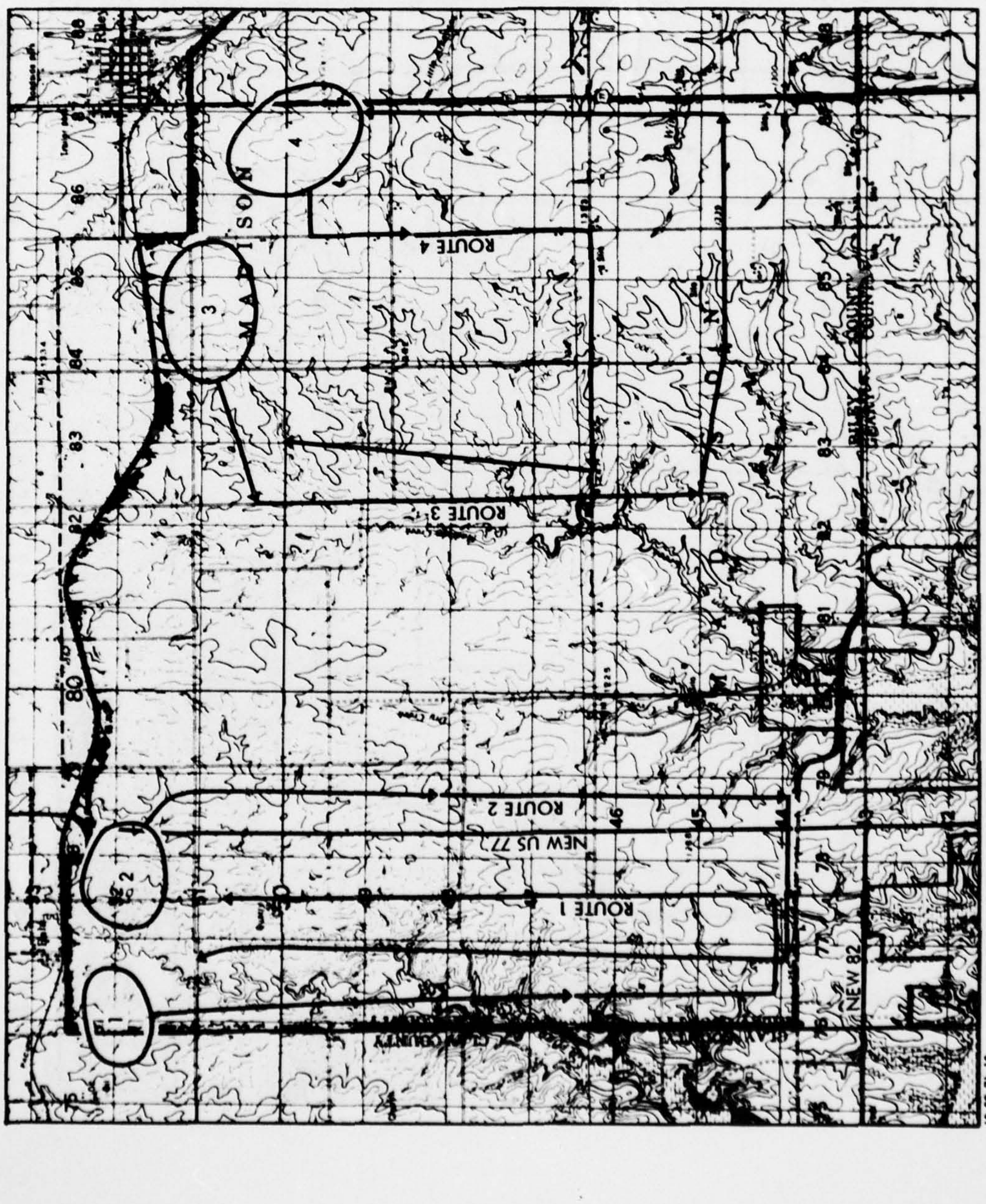

Figure 17. ROUTES 1, 2, 3, 4 (SCENARIOS E1, E2, E3 AND E4)

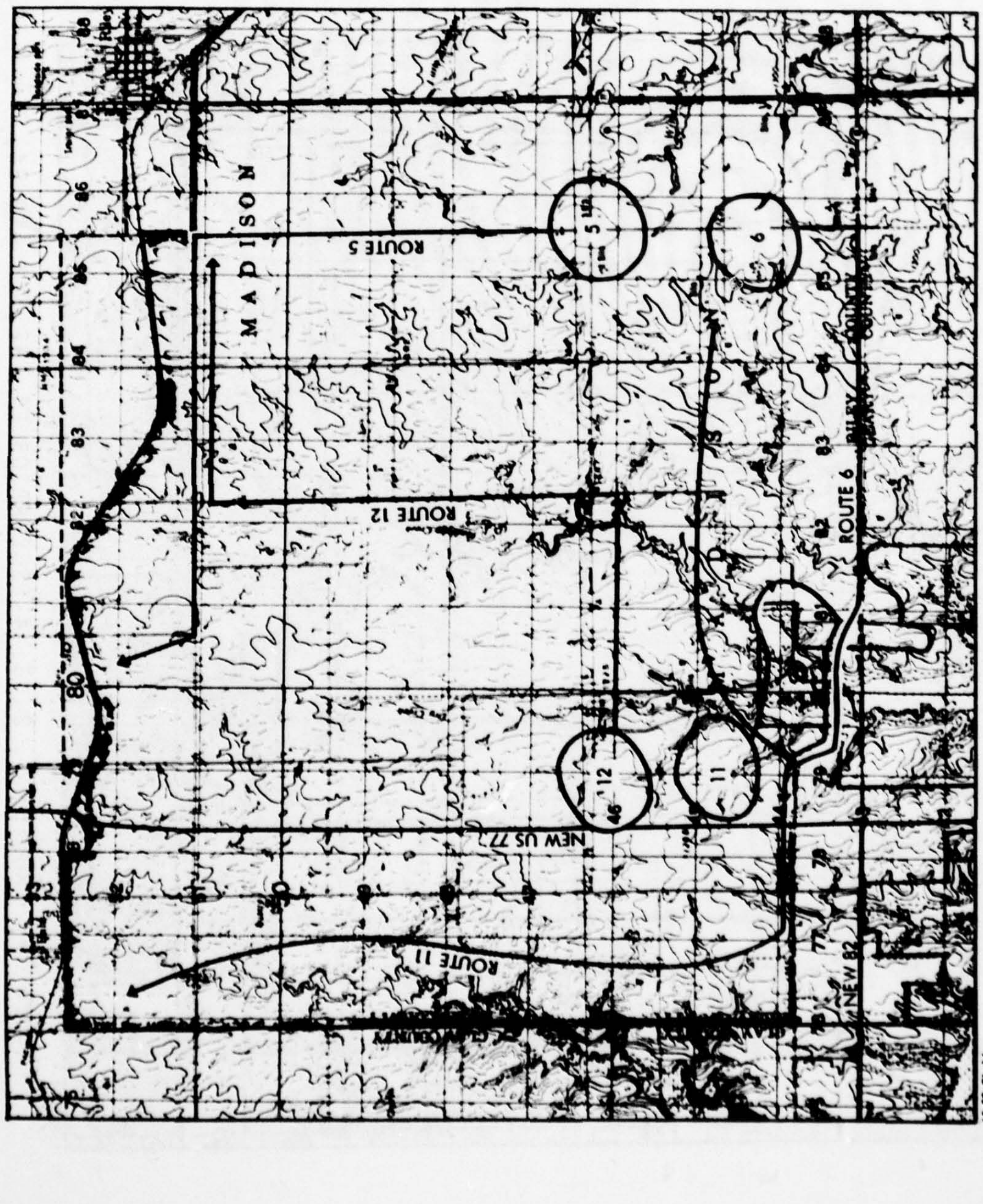

Figure 18. ROUTES 5, 6, 11, 12 (SCENARIOS E5, E6, E11, AND E12)

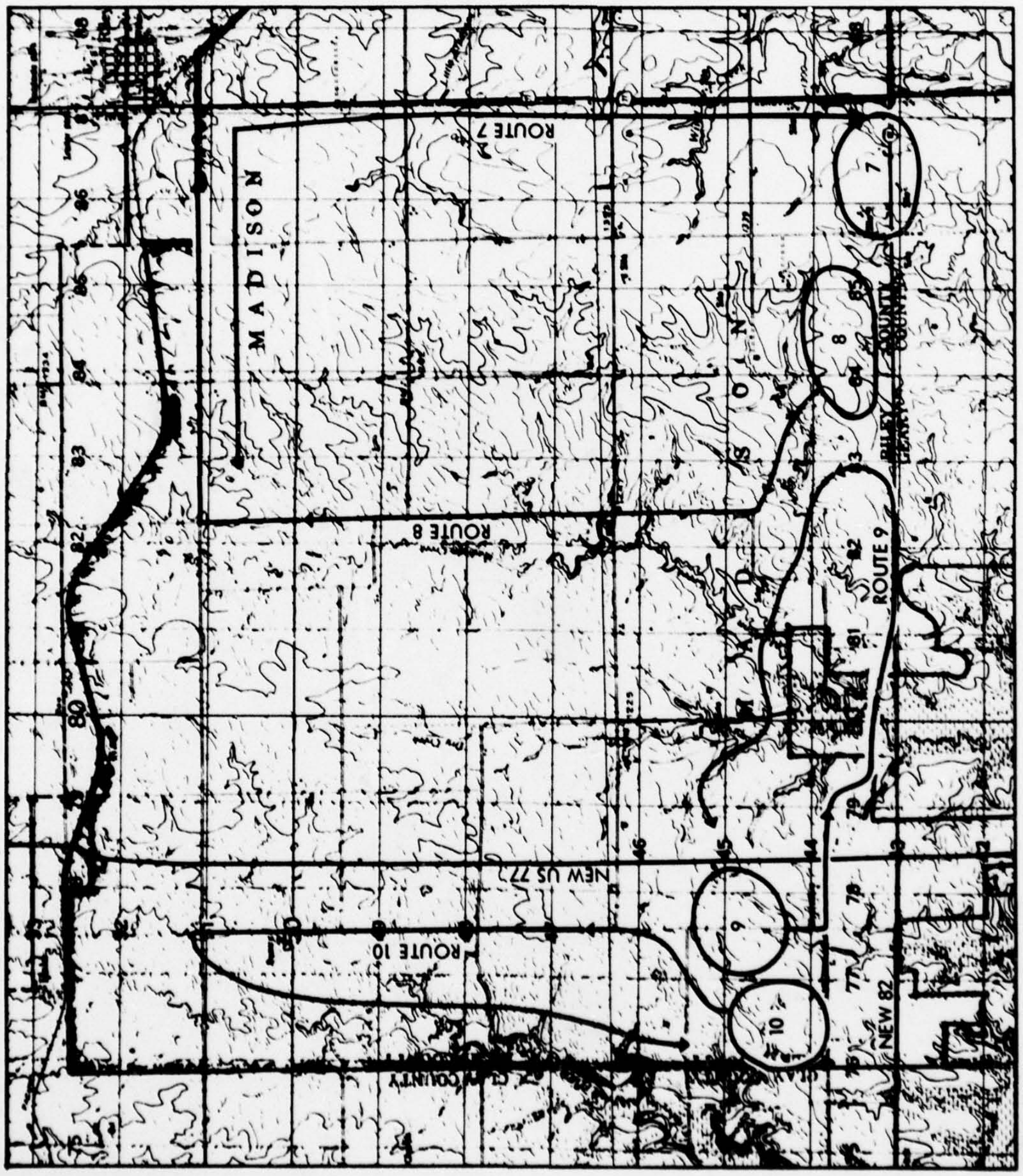

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Figure 19. ROUTES 7, 8, 9, 10 (SCENARIOS E7, E8, E9 AND E10)

Chapter VI

RESOURCES, INSTRUMENTATION, AND DATA REQUIREMENTS

A. RESOURCE REQUIREMENTS

1. Player Elements

The two-sided test will involve a simulated Soviet combined arms company (CAC) being opposed by appropriate levels of MAVERICK-equipped tactical air supporting the allied units in contact. The CAC, on the other hand, is protected to some degree by its location relative to air defense elements of a simulated Soviet combined arms army as described in Appendix C. The required resources for the test include both ground offensive and defensive forces and air forces.

a. Ground

The simulated enemy CAC will be equipped with--

10 tanks
3 APCs (one equipped with SA-7 missiles)
2 ADUs (one quad 23mm; 1 twin 57mm)[1]
1 alerting radar

In addition, representative U.S. defensive forces are required in the attack scenarios and should be equipped with at least two tanks and four APCs.

[1]Because of the importance of the air defense units to the test results, 100 percent spare ADUs should be provided.

b. Air

The size of the armored threat and the need to support other missions (simulated) would appear to indicate a TAC support element of two to four aircraft. The requirement to provide 88 test sorties over a short test period dictates a requirement for backup MAVERICK-capable, instrumented aircraft to ensure continuous test aircraft availability. Since both F-4 and A-7 systems are being evaluated, a minimum of three of each type is suggested.

2. Support Requirements

In addition to the above requirements for player units in the test, it will be necessary to provide appropriate material and personnel support for both air and ground units for approximately 6 weeks of concentrated operations. Additionally, administrative and logistics support of the test director's organization (including analytic support personnel) and the IDA/WSEG staff are required.

B. INSTRUMENTATION, DATA COLLECTION, AND DATA REDUCTION

Test instrumentation will be required in the test to record the tracks of all ground and air vehicles during attacks and the times of occurrence of each important event. Five instrumentation systems are recommended to produce these records:

Range measuring system (RMS)
Voice recording system (VRS)
ADU boresight cameras (PIDRS)[1]
MAVERICK seeker video recorders (video)
Aircraft high resolution cameras

These instrumentation systems will collect most of the test data. Table 9 summarizes the instrumentation scheme; Appendix A presents a detailed plan for instrumentation. Requirements for

[1]Photographic instrumentation and data recording system.

Table 9. INSTRUMENTATION SCHEME

System	Data Provided
RMS (including ground antennas (A-stations), vehicle transponders (B-units) and controller (computer)	Positions of ground vehicles; x-y-z-tracks of aircraft; times of ADU and aircraft events.
VRS (including audio tone generators and F transmitters aboard vehicles, and receivers and tape recorders at VRS station	Times of selected aircraft and ADU events.
Video recording of MAVERICK seeker view	Valid lock-on and the target locked onto.
Aircraft-mounted still camera[a]	Ground scene at time of launch; true or false target; contrast ratio.
ADU boresight camera (PIDRS)	Times of tracking and fire; aid to determining aircraft identification.
Weather observation equipment	Ceiling, visibility, illumination, percent cloud cover, etc.
Manual data collection	Player lists, scorecard, crew briefings, etc.

[a]Boresighted to MAVERICK in the caged position.

data reduced from the records generated by this instrumentation are summarized in Table 10.

Delivery to IDA/WSEG of reduced data covering operations of any given day is expected not later than 1 week after each trial. With certain exceptions, originals or copies of source records produced by instrumentation systems should be delivered to IDA/WSEG not later than 1 week after the end of test operations. A schedule and specification of data to be delivered are included in Appendix A.

Table 10. SUMMARY OF REQUIREMENTS FOR TEST DATA

	MAVERICK Prelaunch Activities
Per Trial	Test condition set identification; total number of aircraft in flight
Per Test Sortie	Aircraft identification; B-unit number; crew identification
Per Attack	No. of passes; target array detection (time, slant range to target array[a], and relative altitude[b])
Per pass	No. of launches; 1st Slew Enable, representing event at selection of first specific target to attack (time, slant range to target, relative altitude)
Per Launch	Time; slant range to target; relative altitude; valid launch (was missile locked on at time of launch?); lock-on to launch time; if valid launch, vs. true[c] target?
	Aircraft Engagement by ADUs
Per Pass	Exposure to weapons: time aircraft enters and leaves engagement envelope.
Per ADU	Maximum range envelope of ADU; slant range at PCA[d], relative aircraft altitude at entrance, exit and PCA.
Per ADU Engagement	Aircraft identification; ADU events of aircraft detection, begin track, begin fire, and end fire (time, slant range, and relative altitude for each).
Per Aircraft Pass	Plot of x-y (z noted) track of aircraft as a function of time (or computer record of x-y-z history of aircraft flightpath).

[a]That is, to the centroid of target array.

[b]The difference between aircraft altitude and the average elevation of the target array.

[c]A "true" target is a threat vehicle (e.g., tank, APC, or ADU); a "false" target is anything else locked on (e.g., a bush, tree, shadow, or non-threat vehicle).

[d]Point of closest approach.

The following paragraphs describe briefly each of the required instrumentation systems and how it will be employed in the data collection program.

1. <u>Range Measuring System</u>

The RMS is the primary instrumentation system. Its operation is shown schematically in Figure 20. This system collects data from which x-y-z position as a function of time can be calculated for every vehicle in the test. The RMS also records the occurrence of most events of importance.

The RMS system is controlled by a computer (Varian 620), which governs timing of system operation and records and processes the data gathered by the RMS. A C-station is the communications interface between the computer and the field components of the RMS. The RMS has several fixed A-stations from which ranges to the test vehicles are measured. Each vehicle carries a B-unit that communicates with A-stations. The B-unit contains a transponder, an antenna, and an event input unit. Ranges between an A-station antenna and a B-unit is determined by the delay between transmission of a signal from the A-station to the B-unit and receipt at the A-station of an acknowledging signal from the B-unit.

The computer controls the sequence and timing of the range interrogations. Each commanded interrogation is transmitted to the C-station from the computer and thence to the A-station. After B-unit interrogation, the A-station composes and transmits a message back to the C-station indicating the measured range to the B-unit (or indicating no response from the B-init). The C-station then transmits this range information to the computer. The D-station is simply a relay between C- and A-stations.

The RMS can also be used to record events. The B-unit has an input into which a binary code can be entered by switches mounted on a special box or by electrical switching within other

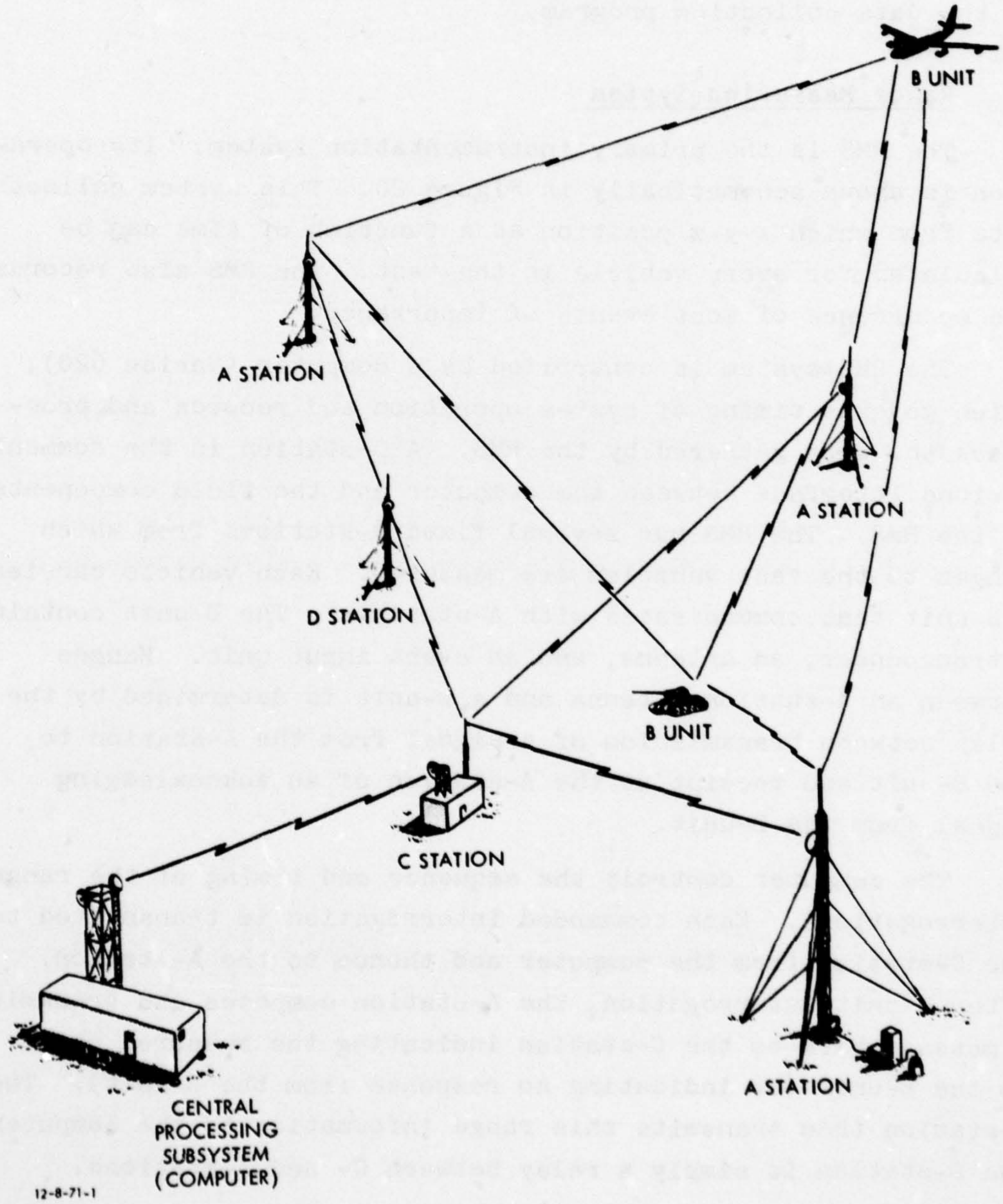

Figure 20. SCHEMATIC REPRESENTATION OF RMS OPERATION

equipment. The switch settings can cause the binary code to be transmitted from the B-unit to the computer via the A- and C-stations. The computer records the binary code for later decoding into predefined events. Thus, equipment or personnel in the test can be conditioned to inject certain events into the RMS.

2. Voice Recording System

The VRS is designed to record communications transmitted over the various radio channels by the test participants. The recordings are made on magnetic tape and are accompanied by a synchronous time signal code. When the tapes are replayed, equipment of the VRS displays the recorded time code, allowing reconstruction of the time of each communication.

Specific audio signals are transmitted over RF channels during the test to indicate certain events. These signals are either voice codes uttered by test personnel or tones automatically generated and transmitted in response to some equipment function. As examples, detection events are transmitted oral code words, and MAVERICK launch is indicated by an automatically transmitted audio tone.

3. ADU Boresight Cameras (PIDRS)

The PIDRS is a 16mm movie camera mounted on each ADU and boresighted to the optical site. The camera can be electrically controlled, thus exposure of film can be correlated with some electrical function of the weapon (slew in this case). The PIDRS also has provision for recording a time code image in the margin of the film. Therefore, each PIDRS is associated with either a time code generator and electronic clock, or a time code receiver.

4. Video

The view of the MAVERICK seeker head is recorded on a video tape recorder. Also recorded on the video tapes are the seeker gates that indicate the object locked onto. A video recorder is carried on each aircraft and covers each pass made by an aircraft.

5. Aircraft Still Camera

The still camera records the ground area around a target at the moment of simulated launch. A telephoto lens and high resolution film are used to obtain an unambiguous identification of the type of target. These photographic records will also be used to obtain quantitative values of contrast ratio of the target at time of launch.

6. Summary Instrumentation Requirements

Table 11 summarizes the events to be recorded during the test, and the instrumentation systems to be used.

Table 11. EVENTS REGISTERED BY INSTRUMENTATION

Event	Instrumentation
ADU slew (i.e., turrent power)	RMS, PIDRS
ADU detection of aircraft	VRS
ADU begin tracking	PIDRS
ADU firing (i.e., trigger depressed)	PIDRS, RMS
SA-7 lock-on	RMS
SA-7 launch	RMS
Pilot detection of target array	VRS
MAVERICK slew[a]	RMS, Video
MAVERICK launch	RMS, VRS, Video

[a]Permits derivation of time of target selection and lock-on.

APPENDIX A

INSTRUMENTATION, DATA REQUIREMENTS, AND DATA REDUCTION

F. G. Stahl

CONTENTS

AD-A060 070 INSTITUTE FOR DEFENSE ANALYSES ARLINGTON VA SYSTEMS E--ETC F/G 16/4.1
MULTI-SERVICE TEST AND EVALUATION: MAVERICK TWO-SIDED TEST DESI--ETC(U)
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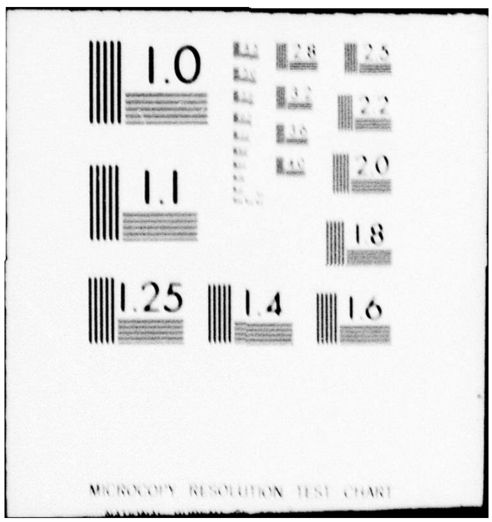
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MICROCOPY RESOLUTION TEST CHART

Chapter I

INTRODUCTION

This appendix presents suggested plans[1] for instrumentation, for applications software of the range measuring system (RMS) computer, and for reduction of data collected by the instrumentation system during the spring 1972 two-sided test of the MAVERICK missile. The instrumentation and data reduction plans are aimed at satisfying the data requirements spelled out in Annex 1 for MAVERICK prelaunch operations.

Chapter II describes instrumentation for the test. Chapter III suggests a software design for the RMS computer that will operate the RMS and reduce the RMS data to printed reports. Chapter IV suggests a plan for reduction of instrumentation records. Annex 1 presents IDA/WSEG data requirements for the test and displays a suggested data recording format. Annex 2 lists events that can occur during the test and that are to be instrumented. Annex 3 suggests sites for the A-stations of the RMS and an evaluation of the corresponding coverages to be expected.

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[1]The material in this appendix supersedes that contained in earlier publications, namely:
IDA Note N-797, Preliminary Report on Instrumentation for MAVERICK Two-Sided Testing, F. G. Stahl et al, October 1971.
IDA Note N-801, Overall Specification for RMS Applications Software for MAVERICK Two-Sided Test, F. G. Stahl, October 1971.

Chapter II

RECOMMENDED INSTRUMENTATION

A. RANGE MEASURING SYSTEM

The RMS consists of the ranging and event detection equipment and the controlling computer and software.

The RMS is a flexible and useful system and has substantial potential in a variety of test applications. It is believed the system can provide positional data on ground and air vehicles sufficient to the needs of MAVERICK testing with the following stipulations: first, the system should be configured as described below to obtain continuous and accurate aircraft tracking; and second, the system is unlikely to directly provide accurate measurement of the elevation (z coordinate) of ground vehicles. Measurements of aircraft altitude, however, should be adequately accurate.

1. Configuring the RMS

Based on the experience with the RMS now installed at Hunter Liggett Military Reservation (HLMR), problems with tracking high performance aircraft appear to be caused by paucity of ranging responses between the ground A-stations and the B-units aboard the aircraft. The following five steps are suggested to improve ranging response during the two-sided test.

a. Use of Micro B-Units

The greater duty cycle of these units permits substantially more frequent rangings than that of the standard B-unit.

Specifically, each aircraft should be interrogated as often as possible by all active A-stations.[1] Further, the greater transmitter power and receiver sensitivity of micro B-units should increase the range at which A-stations and B-units can properly interact.

b. <u>Use of Selected A-Station Antennas</u>

Antennas for the various A-stations of the RMS can be selected to optimize performance for aircraft or ground vehicles. Evaluation[2] of alternative antennas for A-stations shows that the shaped-beam antenna[3], if it meets its specifications, is best for high altitude (that is, above 10,000 feet) aircraft. Next best is an antenna of the discone type. The current antenna (eight dipole pair colinear array) is best for communications between A-stations and ground units.

c. <u>Installation of Two B-Units on Each Aircraft</u>

Substantial loss of ranging data can occur when aircraft maneuvers cause the airframe to shield a single B-unit. Two B-units associated with ventral and dorsal antennas, respectively, should minimize shielding. Computer software to be developed will treat responses from both B-units together for purposes of position calculation. Evaluation of alternative antennas for B-units mounted on aircraft show that those of the blade type are probably optimal for RMS operation.

d. <u>Quick Detection and Correction of A-Station Faults and Failures</u>

Real time computer software can continually check on the apparent operability of each A-station, as indicated by the

[1]For 12 A-stations, each aircraft micro B-unit should accept at least four range interrogations per second if the short message format is used to enter events.

[2]D. A. Dobson, <u>RMS-2 Antenna Investigation</u>, IDA Note N-803, November 1971

[3]Specification Drawing No. 14-1011-1, 24 September 1971.

validity and frequency of messages received. Also, it can examine and display any faults in each A-station as detected and communicated by the hardware at the station. This would expedite replacement of critical A-stations and repair of others. Further, the A-stations should be maintained in a high state of operability.

e. <u>Improving Software</u>

It is believed that the statistical techniques used to derive estimates of B-unit coordinates from RMS ranges can be improved. A subsequent publication will describe alternative techniques.

2. A-Station Coverage

The adequacy of employing a total of 12 A-stations (with three additional backup units) for instrumenting operating areas at Fort Riley is addressed in Annex 3. Five fixed and seven mobile A-stations can provide triple A-station coverage over 90 percent of each of the four test areas.

B. VOICE RECORDING SYSTEM

A VRS can record certain events that are difficult to enter into the RMS without disturbing the authenticity of test operations. Target detections are examples of such events. A VRS also appears to be a necessary adjunct to the RMS for redundancy of event recording. It serves to verify the event data recorded in the RMS and as a backup to failure of field event entry instrumentation of partial failure of the RMS itself. It appears that 5 channels (discrete frequencies) will be needed:

- Aircraft (UHF)
- ADUs and SA-7 (VHF)
- APCs (VHF)
- Tanks (VHF)
- Unit command (VHF)

An additional tape track is dedicated to recording IRIG time.

Some events should be entered into the VRS by tones generated at the field unit. Audio tones entered over the same RF channel should be sufficiently separated in frequency to readily distinguish the player transmitting the event.

Reduction of VRS data will probably have to be manual because special, and therefore expensive, equipment would be needed for automatic reduction.

One second resolution of time in the VRS appears adequate, especially since the RMS system is configured to provide a finer resolution of times of aircraft launch events.

The VRS must record IRIG time and permit display of recorded time during playback. High speed positioning of a tape to a dialed-in time does not appear to be a necessary feature.

C. AIRCRAFT

Each MAVERICK aircraft participating in the test should be equipped with the following instrumentation.

- TGM (or equivalent modified missile
- 2 micro B-units
- Equipment to automatically enter MAVERICK events into the RMS system
- Generator of audio launch tone
- High resolution still camera
- Video tape recorder, Sony-compatible

The micro B-units should be associated respectively with ventral and dorsal fuselage antennas. Stub-type antennas should be used as discussed above. Installation of two B-units on each aircraft appears necessary to improve the response to A-station interrogations and hence the accuracy of aircraft positions estimated by the RMS system.

Analysis of MAVERICK system performance will focus on launch event occurrence. Therefore, two systems are needed

to ensure redundancy in recording the launch event: the RMS and the VRS. It is proposed that normal switch activation for (simulated) launch also automatically cause entry of a launch event into the RMS system and, simultaneously, generation and transmission of an audio tone on the UHF communications net used by the aircraft and FAC, which is recorded by the VRS. Each aircraft should have a clearly distinguishable tone selected for it. The signal that causes entry of an RMS launch event entry should be adequately conditioned to eliminate spurious launch event entry but should cause entry of actual launch events with high probability.

Event data sufficient to estimate the time of slew and lock-on should also be entered into the RMS system from the aircraft. It is intended that these data be used to identify (1) time of target selection as indicated by initiation of slew, and (2) large delays between lock-on and launch.

The time at which the pilot visually detects one or more targets is needed to evaluate the MAVERICK system. This event can be entered into the VRS by spoken code words. Detection is defined here as the visual recognition that causes the pilot to attempt tactical procedures leading to lock-on (i.e., which causes the pilot to begin maneuvering the aircraft so that the targets are aligned to a standard position on the pipper). Reclassification of the targets as false should also be recorded by the VRS.

The video recording of images from the seeker head is adequate for determining which feature the missile was locked onto. It does not appear to be adequate in all cases, however, for unambiguous determination of whether the target is a true target (i.e., threat vehicle) or false target (e.g., tree, bush, or terrain feature). It is recommended that a high resolution still camera be installed and used to photograph the target area for confirmation of the target type. A camera similar to

that utilized for contrast ratios in the September experiment will work. Monochrome film should be used for maximum resolution. Also, cameras with larger negative areas than the 35 mm used in the experiment can be used, if available, to further enhance the resolution. The focal length of the lens used on the camera should be selected to ensure photographic coverage of the area in which the targeted vehicle is located. This area need not include the whole area accessible by the seeker head with maximum slew if in practice the aircraft is aligned with the target during the lock-on and launch sequence.

The still camera should be activated automatically at launch to avoid interference with aircrew activities. One frame at the time of launch is adequate and permits complete mission coverage from a normal magazine load of 36 frames; an initial frame should be exposed pre- or post-flight to identify data such as date, aircraft tail number, and time of day.

Film processing is needed to estimate target contrast ratios and prints for target classification. Therefore, the camera must be compatible with this processing.

The video tape recording of the MAVERICK seeker view as practiced in the MAVERICK tests appears adequate, except that direct recording on a commercially available system (e.g., Sony-type) would reduce the cost of analyzing the recordings.

One UHF radio should be sufficient for both communications and instrumentation needs.

Aircraft that are not equipped with MAVERICK systems (such as a Tiseo-equipped aircraft) must be equipped with B-units if they fly in the test area so that aircraft subject to air defense engagements can be positively distinguished.

D. AIR DEFENSE UNITS (ADUs) (SIMULATED QUAD 23MM AND TWIN 57MM)

Soviet air defense guns will be simulated by U.S. Army Vulcan systems. Each Vulcan should be equipped with the

following instrumentation:

- 1 micro or standard B-unit
- Trigger-activated RMS event entry
- Slew-activated PIDRS boresighted camera
- 2 VHF radios
- Tone generator

The primary events of analytical interest are when the gunner was actually able to commence tracking an aircraft target and when fire occurred. Experience at HLMR shows that recording these events should be automated so as to interfere as little as possible with trained procedures. It is suggested that the PIDRS camera and the RMS event entry should be electrically activated whenever the weapon is slewed (i.e., the power control switch is activated). Reduction of the exposed film will distinguish the actual beginning of tracking time.

The PIDRS camera should record IRIG-type time on the film, for which time reference equipment is needed. Also, if possible, the film should be optically marked whenever the trigger is depressed. The PIDRS camera should be bore-sighted to the weapon on the Vulcan, and the automatic lead should be disabled so that sweep of the weapon coincides with the optical track. The frame rate should be low to minimize the need to change film during operations; a lower limit on frame rate is 10 frames per second. An average of 9 minutes of film will be used by each ADU each trial; variations up to a total of 15 minutes of film are to be expected.

Firing of the weapon should cause entry of fire events into the RMS and marking the film while the trigger is depressed. If it is not possible to mark the film exposed in the PIDRS camera, then depression of the trigger should cause transmission of a tone to the VRS. Distinct tones should be used for each Vulcan.

Data regarding target detection by the crew of the ADU should be entered through a VHF radio into the VRS. The vehicle commander transmits a code word (e.g., "target"), followed simply by his player number, to indicate target detection.

The second radio is needed for the company command; however, voice early warnings should be transmitted on the same frequency as used to transmit ADU target detections.

E. SIMULATED SOVIET SA-7s

An SA-7 will be simulated by a man-carried missile launcher traveling with an APC. The APC should be equipped with:

- 1 micro or standard B-unit
- Automatic RMS event entries
- VHF radio

The simulated SA-7 missile is instrumented to inject events into the RMS corresponding to lock-on and launch events. Detection events will be entered into the VRS by voice code. Since no cameras are to be used to document the operation of this weapon, an observer traveling with this APC will verify that simulated launch occurred during a valid lock-on.

Identification of A/C ?

F. TANKS AND APCs

Several of these vehicles should each be equipped with:

- 1 micro or standard B-unit
- VHF radio

It is not anticipated that active countermeasures will be carried and employed by individual vehicles during the two-sided test. Therefore, only vehicle location is needed of these units.

Analysis of the MAVERICK two-sided test does not require that every APC and tank be equipped with a B-unit. A minimum

requirement is that each of the three tank platoon leaders' tanks and the lead APC be equipped with a B-unit. These are, of course, in addition to those required for the air defense weapons. Thus, a minimum of seven B-units are needed for the ground threat vehicles, assuming the SA-7 travels in other than the lead APC.

There are no unusual requirements for radios. The communications net will be recorded in the VRS, which should provide a record of commands for special maneuvers or actions.

G. OTHER RECORDS

1. Weather Data

The following items of weather data should be collected:

- Ceiling
- Present cloud cover
- Visibility
- Ambient illumination (i.e., incident skylight)
- Winds
- Precipitation
- Pressure

Other data such as temperature, relative humidity, and dew point would be useful, but are not necessary.

It is suggested that the data be collected as close to the beginning of each trial as possible and that weather changes, particularly changes in ambient illumination, ceiling, visibility, or percent of cloud cover, taking place during any trial also be noted.

2. Player IDs

The correspondences between B-unit number, player numbers, and vehicle bumper or tail numbers should be recorded each day. It is recommended that the player numbers be used to identify ground units on all reduced data and computer output. Cutoff tail numbers will be used to identify air units.

3. Scorecard

An observer working with the FAC should create a scorecard showing the air operations accomplished during each trial. By monitoring the FAC/aircraft communications, data can be entered on the scorecard showing wristwatch time (which should be within a minute of IRIG time) when each aircraft commenced each tactical pass. If possible the scorecard should show general descriptions of the attack profile (e.g., roll-in direction, pull-out direction). It should also show any unusual occurrence that would help explain peculiarities in collected data.

4. Crew Briefing/Debriefing

Crew briefing information that shows planned tactics or modifications to developed tactics should be retained and will be needed in the test analysis. Debriefing material should show any unusual difficulties for each aircraft related to MAVERICK or data collection operations and equipment. It would also be helpful if this material showed crew comments on the reasons for any degradations in expected performance of the combined aircraft/MAVERICK system (such as close-in launches). The knee cards should be retained as they may prove useful in the post-test analysis.

5. Early Warning Simulation

The method of simulating radar early warning should be documented. Specifically, the capability of the radar used and the conditions under which a warning is communicated to the field units should be described.

Chapter III

RMS APPLICATIONS SOFTWARE

A. INTRODUCTION

This chapter presents a design of an applications software package for the RMS used in the two-sided test. The software package is designed to control the RMS during test operations and to reduce the data collected during the test by the RMS to forms most usable in subsequent test analysis. The MAVERICK real time program performs the first function. It controls B-unit interrogation, displays data allowing detection of RMS component failures, and logs data collected by the RMS on magnetic tape for later reduction.

The second function (i.e., processing the logged data) consists of two steps. Statistical techniques are applied in the first step to develop estimates of positions of all units during test operations. This program produces a magnetic tape containing a condensed history of the operations. The history consists of position estimates, probable quality of the estimates, and recorded events. The second step produces reports from the history tape. These reports essentially show vehicle and aircraft positions and events through time, along with ranges between the aircraft and selected ground vehicles.

The proposed software system has the same fundamental structure as had the system used for the RMS-2 at HLMR, except that statistical derivations of smoothed vehicle and aircraft tracks is not performed by the real time program. This function is moved to a post-processor to allow greater flexibility in processing of range measurements.

In detail, however, the software package should incorporate several unique features important to the two-sided test. This means that the package must be specially constructed. These features include:

- Optimization for micro B-unit operation
- Positional estimation program adequate for high-performance aircraft
- Provision for handling two B-units on one aircraft
- Partial reduction of RMS data
- Production of output reports oriented specifically to the MAVERICK two-sided test

The proposed software components are described in the paragraphs below. Annex 2 contains a list of test events which are to be handled by the RMS.

It is intended to suggest overall software specifications. Detailed specifications regarding I/O formats, control parameters to be input at run time, RMS and computer I/O failure detection and recovery procedures and capabilities, use of interrupts, etc., are generally not spelled out but should correspond to good programming practice and should provide reasonable flexibility.

B. REAL TIME PROGRAM

The real time program is run during test operations. The program envisaged for the spring test has four functions:

- Control of B-unit interrogation
- Storage of B-unit commands and responses
- Real time detection and display of failures experienced by RMS components
- Real time display of RMS failures

These four functions are duscussed in the following sections.

1. <u>B-Unit Interrogation</u>

B-unit interrogation serves two purposes: first, to obtain ranging measurements between A-stations and B-units; second, to register events entered into B-units. The critical parameters of B-unit interrogation are (1) the rate at which the B-units are interrogated, and (2) selection of A-stations to perform interrogations.

Specifically, the MAVERICK real time program should be programmed to interrogate the aircraft B-units by all A-stations as often as possible during each second.[1] The B-units of ground vehicles need be interrogated for ranges fewer times per second; however, they should be checked for event entry more often. It is suggested that each B-unit of a ground vehicle be interrogated by each A-station once per second and up to five additional interrogations be performed to ensure event entry. It is probably best to interlace the aircraft and ground vehicle interrogations. Thus, in each quarter of a second[2] the following interrogations should be performed:

(1) Interrogate each B-unit on ground vehicles using approximately a quarter[3] of the A-stations.

(2) Interrogate each B-unit for which no valid response was obtained in Step (1) using the last A-station through which a valid response was received from the B-unit

(3) Interrogate each aircraft B-unit using all A-stations.

---

[1]Assuming that the short message format is used for event entry and that the duty cycle of a micro B-unit is 12 times that of the standard B-unit, it ought to be feasible to interrogate each aircraft micro B-unit using each of 12 A-stations at least five times per second; however, other factors can also limit this rate.

[2]Assuming a four times per second interrogation rate on aircraft B-units.

[3]A different set of A-stations is used in each quarter of a second.

2. Storage of B-Unit Responses

The MAVERICK real time program should store images of all RMS responses on magnetic tape for later processing. This tape should be headed by an initial record containing the usual parameters such as number and locations of A-stations, number and addresses of B-units, etc.

A real time data collection program will be provided with the computer system. This or any similar output control program appears to be satisfactory for handling the associated I/O and physical formatting functions.

3. Fault Detection and Display

The A- and D-stations provide automatic indications of certain faults (i.e., conditions indicative of incipient failure) occurring at the stations. These faults include high temperatures and low fuel level. The real time software should interrogate these fault indicators before and after each run and identify faults and the faulty station. Figure A-1 shows a prototype for this output.

4. System Performance Display

The remaining major function of the real time program is to print measures of system performance, which permit quick

```
XXXXXX      A/D DIAGNOSTICS
            A/D STN NBR    XXX   XXX ...
            FAULT CODES    XXX   XXX ...
  (IRIG Time)
    Notes:  1.  Space for 20 units.
            2.  Output once each at beginning
                and end of trial.
            3.  Only faulty stations are listed.
```

Figure A-1. PROTOTYPE A/D DIAGNOSTICS OUTPUT

determination of failures that could otherwise go undetected until after a trial. The suggested printed outputs would indicate three kinds of degradation of RMS performance: poor B-unit response to range commands, absence of event input, and absence of successful ranging through specific A-stations. These outputs are designed to detect major rather than mild degradations. For example, loss of only several events would be detectable only through post-trial analysis involving comparisons among the redundant event recording media, but total B-unit failure would be immediately detectable from this real time output, thus allowing an immediate decision as to whether to continue, postpone, or cancel a trial.

Poor B-unit response to range commands or lack of event entry from a B-unit would be indicated by the B-unit activity report printed every 30 seconds. This output would show, for each B-unit:

(1) IRIG time.

(2) Fraction of interrogation cycles during the last 30 seconds with no valid B-unit responses. (An interrogation cycle is the total time used for interrogation of a B-unit by every A-station. For the interrogation rates suggested above, these cycles are 1 second for ground vehicles and 1/4 second for aircraft.)

(3) Fraction of interrogation cycles during last 30 seconds with valid ranging responses to three or more distinct A-stations.

(4) Percent of invalid event messages received in last 30 seconds. (A valid message should have only one bit set.)

(5) Number of seconds in last 30 seconds in which valid events were received.

(6) Total number seconds since beginning of trial in which events were received.

Figure A-2 shows a prototype of this output.

```
XXXXXX      B-UNIT ACTIVITY
            PLAYER NBR                  XXX  XXX...
            B-UNIT NBR                  XXX  XXX...
            PCT NO RESP (30 SEC)        XXX  XXX...
            PCT 3+RESP (30 SEC)         XXX  XXX...
            PCT BAD EVENTS (30 SEC)     XXX  XXX...
            NBR SECS W/EVTS (30 SEC)    XXX  XXX...
(IRIG Time) NBR SECS W/EVTS (TRIAL)     XXX  XXX...

      Notes:  1.  Space for 25 units.
              2.  Output every 30 seconds.
              3.  If a count exceeds 999, print 999.
```

Figure A-2. PROTOTYPE B-UNIT ACTIVITY OUTPUT

Difficulties with individual A-stations other than the faults indicated in the output described above would be indicated by the A-station activity report, which would also be printed every 30 seconds. It would show, for each A-station:

(1) Fraction of seconds in which no range response received through A-station in last 30 seconds.

(2) Fraction of seconds since beginning of trial in which at least one range response received through A-station.

(3) Number of invalid messages received through A-station since beginning of trial.

Figure A-3 shows a prototype of this output.

```
XXXXXX      A-STATION ACTIVITY
            A-STN NBR               XXX   XXX ...
            PCT NO RESP (30 SEC)    XXX   XXX ...
            PCT RESP (TRIAL)        XXX   XXX ...
            NBR INVAL RESP          XXX   XXX ...
 (IRIG Time)

      Notes:  1.  Space for 20 units.
              2.  Output every 30 seconds.
```

Figure A-3. PROTOTYPE A-STATION ACTIVITY REPORT

C. POSITION ESTIMATION PROGRAM

Development of estimates of B-unit position estimates from RMS range measurements is envisaged as a non-real time function. It will be contained in a program which processes the magnetic tape log of RMS activity produced by the MAVERICK real time program and generates a condensed tape of events and estimated positions. This condensed tape is then used by the several post-trial program modules to produce the primary data reports for a trial.

One reason for producing a new, condensed history tape is that the post-trial programs will probably require more than one pass against a history tape. Further it provides an easily used record of RMS results for a trial. Since this tape may be used for further post-test processing on other computers, it should have a straightforward record format. It is suggested that the condensed history tape contain the following data elements:

- IRIG time
- Location of each instrumented ground unit each second
- Ground unit events
- Location of each aircraft each 1/4 second
- Speed of aircraft each 1/4 second (i.e., absolute value of velocity vector)
- Aircraft events
- Number of range responses used in aircraft tracking solution each second
- Number of range responses available for use in aircraft tracking solution
- Flag indicating reinitialization of aircraft tracking solution
- Quality indicators for x, y, z

The mathematical method used by this position estimation program must be selected carefully to provide the best estimates of position permitted by the range measurements data.

The major mathematical tool for statistically generating positional information is the Kalman filter. Experience with this technique has shown that the six-state Kalman filter, already implemented in the HLMR real time program, produces excellent x-y tracks for ground vehicles. The z coordinate is carried in the computation but has insufficient accuracy. Therefore, an input value for z is to be substituted for all calculations that use the output of this filter.

The uncertainty value (acceleration) used at HLMR in the six-state calculations for ground vehicles appears to be good, but the actual value of this parameter should be an input to the filter program.

The application of the Kalman filter method to high performance aircraft tracking in the HLMR experiment was less successful, mainly due to paucity of range measurements. Alternatives to the Kalman filter method will be presented in a subsequent publication.

It has been recommended that two B-units be carried on each aircraft. Therefore, the position estimation program must be able to accept range measurements from one or two B-units in arriving at position estimates for a single aircraft.

D. POST-TRIAL REPORT PROGRAM

The post-trial program is run after the position estimation program. The post-trial program envisioned for the two-sided test will produce three reports:

- Event history
- Ground vehicle tracks
- Aircraft tracks

These reports are produced by processing the magnetic tape that contains the condensed history of operations and that is produced by the position estimation program. The event history is

a quick summary and contains no positional data. The ground vehicle tracks report shows estimates of vehicle location based on statistical processing of RMS range measurements. It also shows all vehicle RMS events and ranges from ADUs to aircraft. The aircraft tracks report shows estimated aircraft positions and speeds, aircraft events, and ranges to ground vehicles. Subsequent paragraphs describe the suggested form, content, and frequency of each of these reports.

1. Event History

This report has a column for each player and a line entry for each second in which one or more events were registered in the RMS. Figure A-4 is a prototype for this report. Column headings should be printed at the top of each page.

The primary purpose of this report is to provide a ready means of correlating events recorded by the RMS with those registered on other types of instrumentation.

```
                              EVENT HISTORY

 IRIG   TANKS AND APCs        ADUs        ST      AIRCRAFT
 TIME    XX  XX ... XX       XX  XX       XX     XX    XX    XX    XX

XXXXXX   XX  XX ... XX       XX  XX       XX     XX    XX    XX    XX
   .     .   .      .        .   .        .      .     .     .     .
   .     .   .      .        .   .        .      .     .     .     .
   .     .   .      .        .   .        .      .     .     .     .

        Space for up to two event codes
        Player numbers
```

Notes: 1. Space for up to 14 tanks and APCs, two ADUs, one APC simulating an SA-7,* up to four aircraft.
2. "ST" means "SA-7."

*The SA-7 system will be simulated by an APC; however, this vehicle should be treated as a third, but distinguishable, ADU.

Figure A-4. PROTOTYPE FOR EVENT HISTORY REPORT

2. Ground Vehicle Tracks

The ground vehicle report shows the track and event history for every ground vehicle. The output contains a line for every vehicle for each second that has one or more events registered for any of the vehicles. In the absence of events, track information is output every 5 seconds. This report also prints the slant range between the estimated positions of each ADU and each aircraft whenever track data is printed.

Three sheets are needed to display all the columns of data printed (for about 55 lines of data each). Figure A-5 shows a prototype for the tank and APC position information and must be broken into two sheets; IRIG time should appear on both. The center of gravity of the targets should be computed based on estimated tank and APC positions. Which vehicle positions are included in the center of gravity calculation should be a run time option controlled by input cards.

```
                         TANKS AND APC TRACKS

ELEVATION = XXXXX

  IRIG          TARGET          PLAYER NUMBER
  TIME          C OF G               XX                     XX
                                 X     Y    EVT        X     Y    EVT

XXXXXX     XXXXX     XXXXX   XXXXX XXXXX XXX    XXXXX XXXXX XXX...
  .          .         .       .     .    .       .     .    .
  .          .         .       .     .    .       .     .    .
  .          .         .       .     .    .       .     .    .

Notes:  1.  This report goes on two pages.
        2.  Spaces for up to 15 tanks and APCs.
        3.  x and y coordinates in UTM coordinates.
        4.  Elevation is input.
        5.  Output one line is for every second with
            ground event; otherwise every 5 seconds.
```

Figure A-5. PROTOTYPE FOR FIRST PART OF GROUND VEHICLE REPORT (TANKS AND APCs)

Figure A-6 shows a prototype for the ADU positional information and events report. Included here are the ADU-to-aircraft ranges.

The RMS is not expected to be capable of accurately estimating elevations of ground vehicles. For the relatively flat area selected as the operations site at Fort Riley, the elevation can, however, be taken from a map of the operations area and can be referenced to the elevations of the surveyed A-stations. This elevation can be selected so that the maximum elevation error introduced is no more than 100 feet.[1] The corresponding absolute error in slant range calculations would be substantially less.

3. Aircraft Activity

This report shows the x-y-z positions of each of up to five aircraft. Data lines are printed for every 1/4 second and also show any events (up to three) originating with an aircraft, the speed of the aircraft (i.e., the absolute value of the speed vector), and the slant range from the aircraft position to the center of gravity of the targets. This report should probably be produced for the entire time the aircraft is in the area of operations; however, the generating program should be capable of being controlled by input cards provided for each trial that specify the periods for which this report should be produced. The periodicity of this report should also be controllable at run time by card input. Figure A-7 shows a prototype for this report.

[1]The difference between the highest and lowest locations in Fort Riley operating area is 200 feet.

```
                              ADU TRACKS

ELEVATION = XXXXX

 IRIG          ADU   XX           ADU   XX           SA-7       A/C XXX      ...
 TIME    X      Y   EVT      X     Y   EVT      X      Y   EVT   ADU XX      ...

XXXXXX XXXXX XXXXX  XX  XXXXX XXXXX  XX  XXXXX XXXXX  XX  XXXXX XXXXX  ...
  .      .     .     .    .     .     .    .     .     .    .     .
  .      .     .     .    .     .     .    .     .     .    .     .
  .      .     .     .    .     .     .    .     .     .    .     .
```

Slant ranges and relative altitudes between each pair of ADUs and aircraft (meters)

ADU player number

Aircraft player number (tail number)

Notes:

1. Spaces for 2 ADUs, 1 SA-7 and 5 aircraft.
2. x and y coordinates in UTM.
3. Elevation is input for ADUs.
4. Output one line for every second with ground vehicle event or when aircraft is within an input range of an ADU or SA-7; otherwise every 5 seconds.

Figure A-6. PROTOTYPE FOR SECOND PART OF GROUND VEHICLE REPORT (ADUs)

```
                              AIRCRAFT ACTIVITY
   IRIG    AIRCRAFT XXX                                   AIRCRAFT XXX ...
   TIME    X     Y     RZ    SPD RGE  BRG EVT   X     Y
XXXXXXXX XXXXX XXXXX XXXXX XXX XXXX XXX XXX XXXXX XXXXX        ...
   .       .     .     .     .   .    .   .     .     .
   .       .     .     .     .   .    .   .     .     .
   .       .     .     .     .   .    .   .     .     .
```

Notes:
1. Heading line contain aircraft cutoff tail number (player number) as "XXX".
2. One line output for every 1/4 second.
3. With one space between fields, report width should fit on one sheet allowing data for four selected aircraft.
4. When x and y quality factor exceeds 50 meters, an asterisk should be printed between coordinate fields to right of x or y field respectively.
5. Range is from estimated aircraft position to center of gravity of selected ground targets.
6. RZ is relative altitude of aircraft above ground units. BRG is bearing from aircraft to target array.

Figure A-7. PROTOTYPE FOR AIRCRAFT TRACKS REPORT

E. SURVEY OPTION

The position extimation program should contain a survey option. Under this option, the program will compute and print adjustments to designated A-station locations based upon the result of a trial. This option is particularly important since relocatable A-stations are planned. It will permit a quick check for errors in A-station placement or survey.

This adjustment will be based on vector residuals that are vectors from A-stations to an estimated B-unit position, reduced by a vector with the same direction but with a magnitude equal to the measured range. The vector average of these residuals over a trial is the adjustment for an A-station.

F. FORMATTED TAPE DUMP

A program should be written that will produce a formatted dump of the magnetic tape on which all RMS commands and responses are stored. This program should interpret each command and response to split out and print the logical fields contained therein. For instance, a range command would cause the following fields to be printed:

Range flag
B address
A address
D address

A valid response to this command would cause to be printed:

Validity bit
Message flag
Range
Time

If a message was obtained, a binary representation of the message should be printed, along with the time. Only SCOMs should be used for the MAVERICK RMS; thus, no provision need be made for extended messages.

Words in the copy of the input buffer that indicate failure of response should be similarly formatted. A suggested feature of the format is that each command and the associated responses and messages should be printed on one line. Columns need not be headed since this is an informal output and the format of each line may vary depending on the specific command or response. It may be desirable, however, to prefix the fields of each word by an alphabetic designator of the type of command response, if there are possible ambiguities.

G. PRETRIAL CALIBRATION

The real time program should be usable as a pretrial calibration program to check registration of events from ground units and to make sure all units are identified to the software.

The real time program would be more useful in this function if, as an optional mode, it would print events immediately upon reception. This printout would show the player number, the B-unit address, and the event number or code. This mode would not normally be used during actual test operations, except perhaps to pretest event registration from an aircraft when it first arrives in the operations area.

Chapter IV

DATA REDUCTION

Data reduction is the conversion of data from the forms provided by the instrumentation into forms which are suitable for analytical use. Data reduction implies checking the data records for errors and comparing redundant data records for consistency. This chapter describes data reduction tasks as now envisaged for the two-sided test. Annex 1 specifies IDA/WSEG requirements for delivery of both reduced and raw data.

Based on the instrumentation specified in the previous chapter, the following steps have been identified as needed to reduce the data from the spring test to a form consistent with that specified by IDA/WSEG. This form is presented in Annex 1, along with formats for data sheets corresponding to that form.

A. VRS REDUCTION

This task consists of listening to a replay of the VRS tapes for aircraft and ADUs and the writing down the time, unit source, and identification of each event recorded by this system:

Event Source	Event Name	Indicator
Aircraft	Detection of target array	Code word, pilot
Aircraft	Launch	Tone
ADU, SA-7	Visual acquisition of aircraft	Code word, ADU commander
ADU	Fire (entered into VRS if film not marked)	Tone

Possibly pilot est. of altitude, speed, gz, maneuvers

PRECEDING PAGE BLANK

This reduction task should be repeated for each tape by a different team. The two lists thus produced should be compared and any inconsistencies eliminated by reference to the recordings.

B. VIDEO AND PHOTOGRAPHIC REDUCTION

This task consists of replaying the MAVERICK video (1) to make an inventory of launches covered, and (2) to judge whether each launch was valid (i.e., whether the seeker was locked on at time of launch and, if locked on, whether locked onto a true or false target). This reduction requires use of the still camera photos for the true-false target judgment.[1]

This task should be carried out twice by independent analysts. The reduced data thus produced should be compared and any inconsistencies resolved.

C. AIRCRAFT EVENT CORRELATION

The VRS and video reductions produced by the above two tasks are compared with each other and with the RMS reports. In this task, a final list of launches is prepared, showing degree of coverage by these three sources and noting any inconsistencies among them. The scorecard prepared in the field is also used here. The knee cards prepared by the pilot may be of use in resolving inconsistencies among these data sources. Substantive data from the VRS, video, and RMS are not transcribed onto the list of launches.

D. MAVERICK DATA COMPILATION

This task is preparation of sheets showing MAVERICK (prelaunch) activities, based on data from the RMS, VRS (reduced), video (reduced), and launch list. The form for this data is

[1]The photographs from the still camera will also be used to estimate target background categories ("post-launch categories") and contrast ratios.

shown in Annex 1. The following data items are transcribed onto this form:

Data Item	Source
Trial Number	-
Aircraft Number	-
Attack Number	-
Pass Number	Final List of Launches
Launch Number	"
Times of Events	Correlated RMS Report
Slant Range for Each Event	"
Relative Altitude of Aircraft for Each Event	"
Bearing From Aircraft to Target Array	"
Time Between Lock-On and Launch	"
Whether Valid Launch	Video Reduction
True or False Target	Video Reduction, Still Camera Prints
Post-Launch Category	Still Camera Prints

E. PIDRS REDUCTION

This task is reduction of film exposed on the ADU gun cameras. The written record produced by this task will show:

- Time of initiation of each period of camera operation.
- Time of beginning of tracking
- Times of beginning and ending of fire (if imaged on the film)
- Estimated range to aircraft at some convenient time during each period, along with that time. Range at PCA (point of closest approach) is often convenient.

F. ADU DATA CORRELATION

Reduced PIDRS, reduced VRS, and RMS records are to be correlated to identify inconsistencies of times or of coverage. The times of ADU turret slew registered in the PIDRS and the RMS should coincide. If possible, erroneous times are to be corrected. A list of ADU engagements is drawn up showing times and which instruments produced coverage.

G. SA-7 DATA CHECK

SA-7 detections recorded on the reduced VRS should be checked for consistency with SA-7 lock-on and launch events shown on the RMS output. Non-valid events, as shown by the SA-7 observers report, are to be recorded but marked as not valid. There is no precise check to be performed since each instrumentation system records separate events; however, the relationships among the times of these events can be checked.

H. DEVELOPMENT OF ADU ENGAGEMENT DATA

The reduced VRS, reduced PIDRS, and the RMS data are combined to produce ADU engagement histories (see Annex 1 for form). The following data items are transcribed to create this history:

Data Item	Source
Trial Number	-
Aircraft Number	See text
Attack Number	See text
ADU or SA-7 Number	-
Event Codes	--
Times of Events	PIDRS/VRS/RMS
Slant Range for Events	See text
Relative Altitudes	See text

There are several items on this list that must be developed; they are marked as "See text." The values of these data items

depend on identification of the aircraft under attack, which can be determined by inspecting the RMS output report showing all ranges between ADUs and aircraft. Since the time and range have been estimated from the PIDRS film, it is only necessary then to compare this time and range with those printed by the RMS to determine which aircraft was targeted. In cases of ambiguity, other considerations such as time of engagement, etc., can usually distinguish the aircraft. A valuable source of correlating data is the time of PCA as indicated by the RMS output and the PIDRS film. Once the aircraft is identified, the engagement can be correlated with a specific attack and pass, and the slant range and relative altitude for each event can be lifted out of the RMS output.

A similar procedure is not available for the SA-7 since its employment in the test will generate no photographic record.

I. DEVELOPMENT OF AIRCRAFT EXPOSURE DATA

The aircraft exposure data generated by the RMS are inspected to generate a history of the times and conditions when each aircraft entered the effective envelope of each ADU and SA-7. Specifically, for each air defense weapon, the essential data recorded is the time, slant range, and relative altitude of the aircraft to the weapon at envelope entrance, PCA, and envelope exit. Annex 1 displays a form for this data.

Annex 1

DATA REQUIREMENTS AND FORMS

A. DATA REQUIREMENTS

The following outline specifies data from the test needed by IDA/WSEG to evaluate the MAVERICK system.

1. MAVERICK Prelaunch Activities (on Test Data Sheets)

   a. For each aircraft in each trial:

      Trial number
      Aircraft ID

   b. For each attack in each trial:

      Attack number

   c. For each pass in each attack:

      Pass number
      Time of detection of target array

   d. For each launch in each pass:

      Time of slew initiation
      Time of launch
      Time from lock-on to launch
      Whether valid launch
      True or false target
      Bearing from aircraft to target
      Slant range from aircraft to target
      Relative altitude of aircraft above target
      Post-launch category

2. Aircraft Exposure to Air Defenses (on Test Data Sheets)

For each exposure, i.e., period of flight of an aircraft within maximum effectiveness envelope of each ADU and SA-7:

- Trial number
- Aircraft number
- ADU number
- Attack number
- Times, slant ranges, and relative altitudes at entrance into envelope, PCA, and exit of envelope. Ranges and altitudes are between air defense weapon and aircraft.

3. <u>Aircraft Engagements by Air Defense Weapons (on Test Data Sheets)</u>

a. For each engagement[1] of an aircraft by an air defense weapon:

Trial number
Aircraft number
Attack number
Air defense weapon number (player number)

b. For each event during an engagement:

Identification of event (see Annex 2)
Time of event
Slant range, aircraft to weapon
Relative altitude of aircraft above weapon

4. <u>Trial Conditions</u>

For each trial:

Trial conditions[2]
Date of trial
Approximate starting and ending times of trial

5. <u>Aircraft Crews</u>

For each trial and each aircraft: Crew ID.

[1] Engagement is defined if detection of an aircraft occurred; an engagement is terminated by cessation of gun tracking or by launch of missile.

[2] Values of controlled and uncontrolled test variables including weather data.

6. Aircraft Tracks

A representation of the tracks of aircraft while in air defense envelopes. These tracks can either be x-y plots with annotated altitudes and times or computer-readable magnetic tapes of aircraft x-y-z as functions of time.

7. Unreduced Data

Copies of raw data records produced by the several instrumentation systems. These include:

RMS output reports
Video tapes (Sony-compatible)
Aircraft still camera prints
VRS tapes (1-7/8 ips)
PIDRS movie film

8. Contrast Ratios

Specialized processing of the film from the still cameras aboard the aircraft is required to produce estimates of target-to-background contrast ratios.

B. SCHEDULE FOR DELIVERY OF DATA

IDA/WSEG requires the above data items delivered according to the following schedule:

(1) Reduced and ancillary data (Items 1-5 above): day-by-day 1 week after transpiration of subject trials.
(2) Raw data records (Items 6 and 7 above): 1 week after termination of test.
(3) Contrast ratios (Item 8 above): 1 month after termination of test.

C. MAVERICK TWO-SIDED TEST DATA FORMS

Reduced data should be recorded on copies of the data form shown on the next page. The subsequent three pages demonstrate methods of filling out these forms for the three basic kinds of reduced data.

MAVERICK TWO SIDED TEST DATA SHEET

☐ MAVERICK ACTIVITIES ☐ AIRCRAFT EXPOSURES ☐ ADU ENGAGEMENTS

CARD TYPE	TRIAL #	AIRCRAFT #	ATTACK #	PASS #	ADU # OR LAUNCH #	EVENT CODE	TIME H M S	SLANT RANGE (m)	RELATIVE ALTITUDE (m)	BEARING (°)	LOCK-TO-LAUNCH (sec)	VALID LCH	T/F TARG.	BKGRD. CAT.	

Date of Data ____________ Page ______

MAVERICK TWO SIDED TEST DATA SHEET

☑ MAVERICK ACTIVITIES ☐ AIRCRAFT EXPOSURES ☐ ADU ENGAGEMENTS

CARD TYPE	TRIAL #	AIRCRAFT #	ATTACK #	PASS #	ADU # OR LAUNCH #	EVENT CODE	TIME H M S	SLANT RANGE (m)	RELATIVE ALTITUDE (m)	BEARING (°)	LOCK-TO-LAUNCH (sec)	VALID LCH	T/F TARG.	BKGRD. CAT.		
																Detection
																Slew, Pass 1
																Launch
				01	02	L	142346	3637	1624	280	1	Y	F	1		Launch
				01	03	L	142356	3280	1670	281	3	N				Launch
				02		K	142542	5402	2701							Slew, Pass 2
																Launch
																Slew, Pass 3
																Launch
				03	02	L	143004	2000	1000	266	1	Y	T	2		Launch
			02	02	00	J	144017	5122	2280							Detection
																Etc.

SAMPLE

Date of Data ____________ Page ________

MAVERICK TWO SIDED TEST DATA SHEET

☐ MAVERICK ACTIVITIES ☑ AIRCRAFT EXPOSURES ☐ ADU ENGAGEMENTS

CARD TYPE	TRIAL #	AIRCRAFT #	ATTACK #	PASS #	ADU # OR LAUNCH #	EVENT CODE	TIME H M S	SLANT RANGE (m)	RELATIVE ALTITUDE (m)	BEARING (°)	LOCK-TO-LAUNCH (sec)	VALID LCH	T/F TARG.	BKGRD. CAT.		
[illegible]	023	26	01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							In EnveIop
						[illegible]	[illegible]	257	237							PCA
						[illegible]	[illegible]	[illegible]	950							Out Envelop
					22	A	142341	1000	500							Etc.
						B	142408	428	480							
						C	142439	1000	600							

Date of Data ____________ Page ________

SAMPLE

MAVERICK TWO SIDED TEST DATA SHEET

☐ MAVERICK ACTIVITIES ☐ AIRCRAFT EXPOSURES ☑ ADU ENGAGEMENTS

CARD TYPE	TRIAL #	AIRCRAFT #	ATTACK #	PASS #	ADU # OR LAUNCH #	EVENT CODE	TIME H M S	SLANT RANGE (m)	RELATIVE ALTITUDE (m)	BEARING (°)	LOCK-TO-LAUNCH (sec)	VALID LCH	T/F TARG.	BKGRD. CAT.		
[illegible]	022	26	01	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							A/C Det'n
[illegible]						[illegible]	[illegible]	[illegible]	[illegible]							Begin Track
[illegible]						[illegible]	[illegible]	[illegible]	[illegible]							Begin Fire
						I	142415	1651	873							End Fire
					22	F	142347	8231	6200							A/C Det'n
					22	G	142353	7887	5728							Begin Track
					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							SA-7 Lockon
					[illegible]	[illegible]	[illegible]	[illegible]	[illegible]							SA-7 Launch
																Etc.

Date of Data ______________ Page ________

SAMPLE

UNCLASSIFIED

Annex 2

TEST EVENTS

Two kinds of events are to be defined for the MAVERICK test. The first are those that are entered through the RMS and that are typically persistent through time. The second are those that are of analytical interest in the test and are instantaneous by definition. Events of the second kind are, in some cases, generated from those of the first type; thus there is a need to distinguish between them. For example, MAVERICK slew is an RMS event that is persistent during the time the slew is enabled. On the other hand, initiation of MAVERICK slew is an instantaneous event of analytic interest.

MAVERICK test events and their codes are listed on the following page.

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MAVERICK TEST EVENTS

RMS EVENTS

Event Code	Event Name	Timing Source
1	ADU slew (i.e, turret powered)	
2	ADU fire (i.e., trigger depressed)	
3	--	
4	SA-7 lock-on	
5	SA-7 launch	
6	MAVERICK slew	
7	MAVERICK launch	

ANALYTIC EVENTS

Event Code	Event Name	Timing Source
A	Aircraft entrance into maximum range envelop of air defense weapon	RMS
B	Occurrence of PCA of aircraft to air defense weapon	RMS
C	Aircraft exit from maximum range envelop of air defense weapon	RMS
D	SA-7 lock-on	RMS
E	SA-7 launch	RMS
F	ADU detection of aircraft	VRS
G	ADU begin tracking aircraft	RMS/PIDRS
H	ADU begin firing on aircraft	RMS/PIDRS
I	ADU end firing on aircraft	RMS/PIDRS
J	Aircrew detection of target array	VRS
K	MAVERICK begin slew (= selection of target from array)	RMS
L	MAVERICK launch	RMS/VRS
M	SA-7 detection of aircraft	VRS

Annex 3

A-STATION LOCATIONS AND COVERAGE[1]

A. INTRODUCTION

In order to determine the location of moving ground units at any time during the test, each B-station antenna mounted on a unit must be within the line-of-sight of at least three A-station antennas at all times. It is assumed that each A-station can be a fixed installation or a mobile installation (mounted on a truck) that can be repositioned between trials.

For a given A-station site, the variable terrain will create regions within a test area for which a B-station could be masked from the given A-station. Since there will be only 12 A-stations available for the MAVERICK two-sided test (with three additional stations for backup), it is desirable to optimally choose locations for these A-stations so that the size of the regions within each of the several definitive areas for which a B-station cannot be seen by at least three A-stations is minimized. This, basically, is the problem addressed by this annex.

The next two sections discuss the locations of the Fort Riley test zones and the key constraints on the A-stations. The last two sections discuss the approach to the solution of the problem and the conclusions.

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[1]This annex was prepared by Dr. G. L. Brown.

B. LOCATIONS OF TEST ZONES

The total test area to be used on Fort Riley is divided into four test zones for instrumentation purposes. Each test trial will be carried out within the confines of a single zone.

The approximate boundaries of the total maneuver area are defined in Table A-1 and the approximate boundaries of the four instrumented test zones are defined in Table A-2. Figure A-8 displays the approximate total maneuver area and the four test zones with UTM coordinates as references.

Table A-1. APPROXIMATE BOUNDARIES OF THE TOTAL TEST AREA

West	Clay-Riley County boundary line
East	Highway 77
North	Chicago, Rock Island, and Pacific Railroad tracks
South	Highway 82

C. A-STATION CONSIDERATIONS

Fifteen A-stations are to be utilized for the test. Of these, it is planned to keep three in reserve for reliability problems and only 12 actually used during the test. Of these 12, some are to be operated at fixed sites throughout the test. The remaining stations are to be mobile so that they may be moved to an optimal location to improve coverage for whichever zone is used for a test at a given time. It is desirable to have as many as possible of the 12 sites fixed since reliability is generally lower for mobile A-stations. Also, a fixed site will have greater coverage since a 50-foot antenna can be used (versus a mobile A-station with a 25-foot antenna). The difference in coverage could be significant since the topf of the B-unit antenna is only about 10 feet above the ground.

Table A-2. APPROXIMATE BOUNDARIES OF THE FOUR TEST ZONES

Zone 1

West	Clay-Riley County line
East	Road running approximately parallel to western boundary, approximately 1.7 kilometers east of it
South	Highway 82
North	C, R.I., and P. RR tracks

Zone 2

West	Eastern boundary of zone 1
East	Road running approximately parallel to western boundary of test area, approximately 3.4 km east of it, and extended down to Highway 82
South	Highway 82
North	C, R.I., and P. RR tracks

Zone 3

West	Eastern boundary of zone 2
East	Highway 77
South	Highway 82
North	Road running perpendicular to Highway 77 intersecting it approximately 3.3 km north of the intersection of Highways 77 and 82

Zone 4

West	Road running approximately parallel to Highway 77, approximately 4.8 km west of it
East	Highway 77
North	C., R.I., and P. RR tracks
South	Northern boundary of zone 3

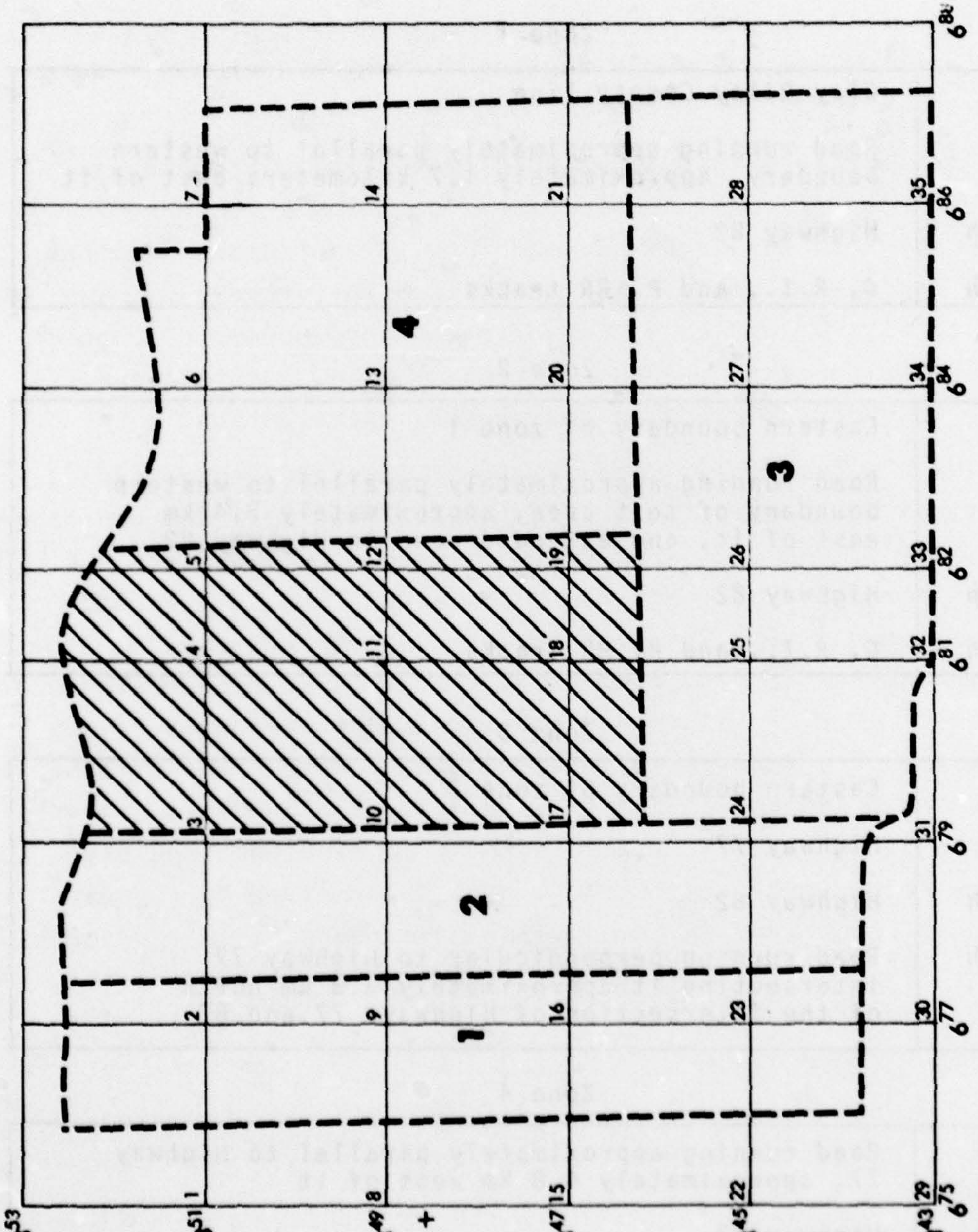


Figure A-8. TEST AREA, ZONES, AND A-STATION SITE RECTANGLES RELATED TO UTM COORDINATES

D. APPROACH TO SOLUTION

The first step was to select a number of potential A-station sites in the vicinity of the maneuver area and to determine for each site the regions for which a ground B-unit would be masked from an A-station at the chosen site.

In order to obtain a number of potential sites throughout the maneuver area, the territory containing the maneuver area was considered to be divided into 35 rectangular regions by the horizontal and vertical UTM lines in Figure A-8. The highest point within each rectangle was then chosen as a potential A-station site. Another potential site, identified as F01 in Figure A-8, was also chosen for investigation.

The Electromagnetic Compatibility Analysis Center (ECAC) determined the highest point within each rectangle and generated an overlay of the test area for each site that displayed the regions for which a B-unit would be masked from an A-station at the chosen site. The overlays were based on 5-second interval elevation data extracted from 1:50,000 maps of the test area. The elevations of non-data points were determined by the use of a four-point interpolation scheme. The effects of refraction were included in generating the overlay; however, the effects of trees were not included. The elevations used for the selected A-station sites were those given by the map, not those determined by the interpolation scheme. For several sites (F01, 21, 32), results were obtained for a 50-foot A-station antenna height; for the remaining sites, results were obtained for a 25-foot antenna.

After the A-station sites were selected and the associated overlays showing the masked regions for each site were produced, the next step was to manually use the overlays to determine for each test zone 12 A-station sites for which less than 10 percent of the zone cannot be seen by at least 3 of the 12 A-stations. At the same time, an attempt was made to have a

number of sites common to all four sets of 12 sites; these could then be considered as fixed sites.

E. RESULTS AND CONCLUSIONS

Table A-3 indicates the locations in UTM coordinates and the map elevations of each site selected as a potential A-station location. The analyses described in the previous section showed that five fixed and seven mobile A-stations could be used to obtain the desired triple coverage of approximately 90 percent of each test zone. Table A-4 indicates the sites involved for each test zone. Repetition of a site number for more than one zone indicates that the same site is used for both zones.

Figures A-9 through A-12 show coverages of zones 1 through 4, respectively. In each figure, the areas covered by five and by seven A-stations are shown as are the portions of these zones not covered. Here, coverage is defined as line of sight between a ground vehicle and at least three A-stations.

It should be noted that the results were based upon the assumption that sites 2 and 13 have only 25-foot antennas even though they were considered to be fixed sites. The use of 50-foot antennas might increase coverage from each of those sites by 10 or 25 percent, which could reduce some of the non-triple covered regions shown in the figures. Also there is the possibility that some of the three reserved A-stations could be used to increase coverage within a zone.

Finally, it should be pointed out that this analysis produced only a first approximation to optimal A-station locations. Final siting should be accomplished by fielding actual RMS units at Fort Riley. In general, this analysis does confirm that 12 A-stations should provide adequate RMS ground coverage for the MAVERICK test.

Table A-3. SELECTED POTENTIAL A-STATION SITES

Site	UTM Coordinates		Map Elevation
	Easting	Northing	
1	676080	4352280	1315
2	678000	4351990	1340
3	680050	4352050	1360
4	681280	4352200	1320
5	683300	4351920	1370
6	684900	4352290	1330
7	687540	4352730	1360
8	676200	4349930	1260
9	677860	4349880	1290
10	679920	4350250	1340
11	681130	4350110	1292
12	683090	4350295	1310
13	684720	4350300	1362
14	687120	4349505	1345
15	675900	4347990	1280
16	678000	4348450	1300
17	680590	4348125	1290
18	681185	4348260	1280
19	683080	4348505	1300
20	684880	4348250	1340
21	687150	4347590	1340
22	676180	4346250	1280
23	677900	4346090	1270
24	680190	4346220	1250
25	681505	4346300	1260
26	683470	4345900	1300
27	785400	4346300	1340
28	686805	4346080	1320

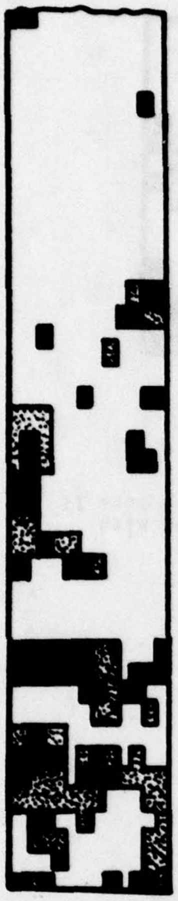
Table A-3 (Cont'd)

Site	UTM Coordinates		Map Elevation
	Easting	Northing	
29	676030	4344080	1250
30	678405	4343800	1272
31	680123	4344500	1240
32	681500	4344260	1260
33	683590	4343520	1300
34	685025	4344200	1320
35	686490	4343500	1340
F01	674935	4348799	1335

Table A-4. A-STATION SITES FOR EACH TEST ZONE

Fixed Sites
2, 13, 21, 32, F01

Zone	Mobile Sites
1	1, 8, 15, 16, 22, 29, 30
2	24, 10, 16, 22, 23, 9, 30
3	24, 26, 27, 31, 33, 34, 35
4	5, 26, 27, 19, 20, 12, 18

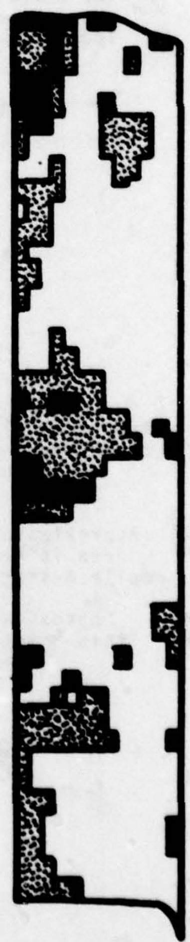


Approximately 60% of the zone is triply covered using five mobile A-stations at locations 1, 8, 15, 16 and 22 in addition to fixed stations.

Approximately an additional 30% of the zone is triply covered using two or more mobile A-stations at locations 29 and 30.

Approximately 10% of the zone is less than triply covered with seven mobile A-stations.

Figure A-9. A-STATION COVERAGE OF ZONE 1

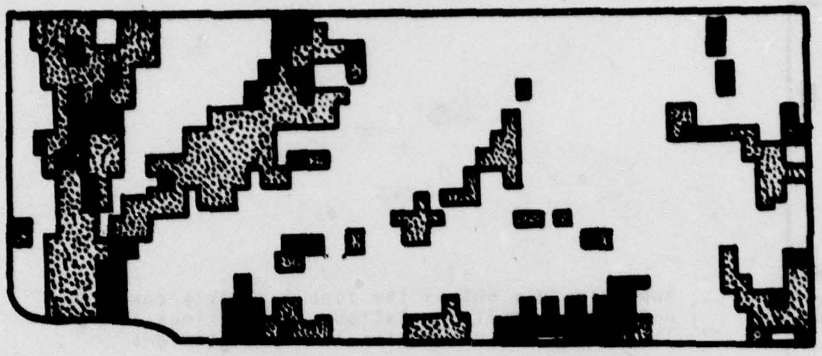


Approximately 65% of the zone is triply covered using five mobile A-stations at locations 9, 10, 23, 24 and 30 in addition to fixed stations.

Approximately an additional 25% of the zone is triply covered using two more mobile A-stations at locations 16 and 22.

Approximately 10% of the zone is less than triply covered with seven mobile A-stations.

Figure A-10. A-STATION COVERAGE OF ZONE 2



Approximately 70% of the zone is triply covered using five mobile A-stations at locations 27, 34, 35, 26 and 33 in addition to fixed stations.

Approximately an additional 20% of the zone is triply covered using two or more mobile A-stations at locations 24 and 31.

Approximately 10% of the zone is less than triply covered with seven mobile A-stations.

Figure A-11. A-STATION COVERAGE OF ZONE 3

Approximately 80% of the zone is triply covered using five mobile A-stations at locations 18, 19, 20, 26 and 27 in addition to fixed stations.

Approximately an additional 15% of the zone is triply covered using two more mobile A-stations at locations 5 and 12.

Approximately 5% of the zone is less than triply covered with seven mobile A-stations.

Figure A-12. A-STATION COVERAGE OF ZONE 4